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| <b>(51) International Patent Classification <sup>6</sup> :</b><br><b>C07C 211/00, A61K 31/135, 31/165, 31/295, 31/40</b>  | <b>A1</b>  | <b>(11) International Publication Number:</b> <b>WO 97/46511</b><br><b>(43) International Publication Date:</b> 11 December 1997 (11.12.97) |
| <b>(21) International Application Number:</b> PCT/US96/20697<br><b>(22) International Filing Date:</b> 11 December 1996 (11.12.96)<br><b>(30) Priority Data:</b><br>08/663,013 7 June 1996 (07.06.96) US<br>Not furnished 6 December 1996 (06.12.96) WO<br><b>(34) Countries for which the regional or international application was filed:</b> AT et al.<br><b>(71) Applicant (for all designated States except US):</b> NPS PHARMACEUTICALS, INC. [US/US]; Suite 240, 420 Chipeta Way, Salt Lake City, UT 84108 (US).<br><b>(72) Inventors; and</b><br><b>(75) Inventors/Applicants (for US only):</b> MUELLER, Alan, L. [US/US]; 2510 E. Skyline Drive, Salt Lake City, UT 84108 (US). MOE, Scott, T. [US/US]; 6152 South Vinefield Drive, Salt Lake City, UT 84105 (US). BALANDRIN, Manuel, F. [US/US]; 9184 South Winter Wren Drive, Sandy, UT 84093 (US). VANWAGENEN, Bradford, C. [US/US]; 3969 South 3250 East, Salt Lake City, UT 84124 (US). DELMAR, Eric, G. [US/US]; 2967 East St. Mary's Circle, Salt Lake City, UT 84108 (US). ARTMAN, Linda, D. [US/US]; 2510 E. Skyline Drive, Salt Lake City, UT 84108 (US). BARMORE, Robert, M. [US/US]; 1172 East Sunnyside Avenue, Salt | Lake City, UT 84102 (US). SMITH, Daryl, L. [US/US]; 4943 S. Murray Boulevard #Y4, Murray, UT 84123 (US).<br><b>(74) Agents:</b> WARBURG, Richard, J. et al.; Lyon & Lyon, First Interstate World Center, Suite 4700, 633 West Fifth Street, Los Angeles, CA 90071 (US).<br><b>(81) Designated States:</b> AL, AM, AT, AU, AZ, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, US, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).<br><b>Published</b><br>With international search report. |   |
| <b>(54) Title:</b> COMPOUNDS ACTIVE AT A NOVEL SITE ON RECEPTOR-OPERATED CALCIUM CHANNELS USEFUL FOR TREATMENT OF NEUROLOGICAL DISORDERS AND DISEASES<br><b>(57) Abstract</b><br><p>Method and compositions for treating a patient having a neurological disease or disorder, such as stroke, head trauma, spinal cord injury, spinal cord ischemia, ischemia- or hypoxia-induced nerve cell damage, epilepsy, anxiety, neuropsychiatric or cognitive deficits due to ischemia or hypoxia such as those that frequently occur as a consequence of cardiac surgery under cardiopulmonary bypass, or neurodegenerative diseases such as Alzheimer's Disease, Huntington's Disease, Parkinson's Disease, or amyotrophic lateral sclerosis (ALS).</p>   |  |   |

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DESCRIPTION

COMPOUNDS ACTIVE AT A NOVEL SITE ON RECEPTOR-OPERATED  
CALCIUM CHANNELS USEFUL FOR TREATMENT OF NEUROLOGICAL  
DISORDERS AND DISEASES

5           This is a continuation-in-part of co-pending  
application U.S. Serial No. 08/663,013, filed June 7,  
1996, which is a continuation-in-part of co-pending  
application U.S. Serial No. 08/485,038, filed June 7,  
1995, which is a continuation-in-part of co-pending  
10   International Patent Application No. PCT/US94/12293,  
filed October 26, 1994, designating the United States,  
which is a continuation-in-part of co-pending  
application U.S. Serial No. 08/288,688, filed August 9,  
1994, which is a continuation-in-part of co-pending  
15   application U.S. Serial No. 08/194,210, filed February  
8, 1994, which is a continuation-in-part of U.S. Serial  
No. 08/014,813, filed February 8, 1993, now abandoned,  
all of which are hereby incorporated by reference herein  
in their entirety.

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**Field of the Invention**

          This invention relates to compounds useful as  
neuroprotectants, anticonvulsants, anxiolytics,  
analgesics, muscle relaxants or adjuvants to general  
anesthetics. The invention relates as well to methods  
25   useful for the treatment of neurological disorders and  
diseases, including, but not limited to, global and  
focal ischemic and hemorrhagic stroke, head trauma,  
spinal cord injury, hypoxia-induced nerve cell damage  
such as in cardiac arrest or neonatal distress,

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epilepsy, anxiety, and neurodegenerative diseases such as Alzheimer's Disease, Huntington's Disease, Parkinson's Disease, and amyotrophic lateral sclerosis (ALS). The invention relates as well to methods of screening for compounds active at a novel site on receptor-operated calcium channels, and thereby possessing therapeutic utility as neuroprotectants, anticonvulsants, anxiolytics, analgesics, muscle relaxants or adjuvants to general anesthetics, and/or possessing potential therapeutic utility for the treatment of neurological disorders and diseases as described above.

#### Background of the Invention

The following is a description of relevant art, none of which is admitted to be prior art to the claims.

Glutamate is the major excitatory neurotransmitter in the mammalian brain. Glutamate binds or interacts with one or more glutamate receptors which can be differentiated pharmacologically into several subtypes. In the mammalian central nervous system (CNS) there are three main subtypes of ionotropic glutamate receptors, defined pharmacologically by the selective agonists *N*-methyl-D-aspartate (NMDA), kainate (KA), and  $\alpha$ -amino-3-hydroxy-5-methylisoxazole-4-propionic acid (AMPA). The NMDA receptor has been implicated in a variety of neurological pathologies including stroke, head trauma, spinal cord injury, epilepsy, anxiety, and neurodegenerative diseases such as Alzheimer's Disease (Watkins and Collingridge, *The NMDA Receptor*, Oxford:



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IRL Press, 1989). A role for NMDA receptors in nociception and analgesia has been postulated as well (Dickenson, A cure for wind-up: NMDA receptor antagonists as potential analgesics. *Trends Pharmacol. Sci.* 11: 307, 1990). More recently, AMPA receptors have been widely studied for their possible contributions to such neurological pathologies (Fisher and Bogousslavsky, Evolving toward effective therapy for acute ischemic stroke. *J. Amer. Med. Assoc.* 270: 360, 1993; Yamaguchi et al., Anticonvulsant activity of AMPA/kainate antagonists: Comparison of GYKI 52466 and NBQX in maximal electroshock and chemoconvulsant seizure models. *Epilepsy Res.* 15: 179, 1993).

When activated by glutamate, the endogenous neurotransmitter, the NMDA receptor permits the influx of extracellular calcium ( $\text{Ca}^{2+}$ ) and sodium ( $\text{Na}^+$ ) through an associated ion channel. The NMDA receptor allows considerably more influx of  $\text{Ca}^{2+}$  than do kainate or AMPA receptors (but see below), and is an example of a receptor-operated  $\text{Ca}^{2+}$  channel. Normally, the channel is opened only briefly, allowing a localized and transient increase in the concentration of intracellular  $\text{Ca}^{2+}$  ( $[\text{Ca}^{2+}]_i$ ), which, in turn, alters the functional activity of the cell. However, prolonged increases in  $[\text{Ca}^{2+}]_i$ , resulting from chronic stimulation of the NMDA receptor, are toxic to the cell and lead to cell death. The chronic elevation in  $[\text{Ca}^{2+}]_i$ , resulting from stimulation of NMDA receptors, is said to be a primary cause of neuronal degeneration following a stroke (Choi, Glutamate neurotoxicity and diseases of the nervous system. *Neuron* 1: 623, 1988). Overstimulation of NMDA

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receptors is also said to be involved in the pathogenesis of some forms of epilepsy (Dingledine et al., Excitatory amino acid receptors in epilepsy. *Trends Pharmacol. Sci.* 11: 334, 1990), anxiety (Wiley and Balster, Preclinical evaluation of N-methyl-D-aspartate antagonists for antianxiety effects: A review. In: *Multiple Sigma and PCP Receptor Ligands: Mechanisms for Neuromodulation and Neuroprotection?* NPP Books, Ann Arbor, Michigan, pp. 801-815, 1992), neurodegenerative diseases (Meldrum and Garthwaite, Excitatory amino acid neurotoxicity and neurodegenerative disease. *Trends Pharmacol. Sci.* 11: 379, 1990), and hyperalgesic states (Dickenson, A cure for wind-up: NMDA receptor antagonists as potential analgesics. *Trends Pharmacol. Sci.* 11: 307, 1990).

The activity of the NMDA receptor-ionophore complex is regulated by a variety of modulatory sites that can be targeted by selective antagonists. Competitive antagonists, such as the phosphonate AP5, act at the glutamate binding site, whereas noncompetitive antagonists, such as phencyclidine (PCP), MK-801 or magnesium ( $Mg^{2+}$ ), act within the associated ion channel (ionophore). There is also a glycine binding site that can be blocked selectively with compounds such as 7-chlorokynurenic acid. There is evidence suggesting that glycine acts as a co-agonist, so that both glutamate and glycine are necessary to fully elicit NMDA receptor-mediated responses. Other potential sites for modulation of NMDA receptor function include a zinc ( $Zn^{2+}$ ) binding site and a sigma ligand binding site. Additionally, endogenous polyamines such as spermine are

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believed to bind to a specific site and so potentiate NMDA receptor function (Ransom and Stec, Cooperative modulation of [<sup>3</sup>H]MK-801 binding to the NMDA receptor-ion channel complex by glutamate, glycine and polyamines. *J. Neurochem.* 51: 830, 1988). The potentiating effect of polyamines on NMDA receptor function may be mediated via a specific receptor site for polyamines; polyamines demonstrating agonist, antagonist, and inverse agonist activity have been described (Reynolds, Arcaine is a competitive antagonist of the polyamine site on the NMDA receptor. *Europ. J. Pharmacol.* 177: 215, 1990; Williams et al., Characterization of polyamines having agonist, antagonist, and inverse agonist effects at the polyamine recognition site of the NMDA receptor. *Neuron* 5: 199, 1990). Radioligand binding studies have demonstrated additionally that higher concentrations of polyamines inhibit NMDA receptor function (Reynolds and Miller, Ifenprodil is a novel type of NMDA receptor antagonist: Interaction with polyamines. *Molec. Pharmacol.* 36: 758, 1989; Williams et al., Effects of polyamines on the binding of [<sup>3</sup>H]MK-801 to the NMDA receptor: Pharmacological evidence for the existence of a polyamine recognition site. *Molec. Pharmacol.* 36: 575, 1989; Saccaan and Johnson, Characterization of the stimulatory and inhibitory effects of polyamines on [<sup>3</sup>H]TCP binding to the NMDA receptor-ionophore complex. *Molec. Pharmacol.* 37: 572, 1990). This inhibitory effect of polyamines on NMDA receptors is probably a nonspecific effect (i.e., not mediated via the polyamine receptor) because patch clamp electro-physiological studies have demonstrated that this inhibition is

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produced by compounds previously shown to act at the polyamine receptor as either agonists or antagonists (Donevan et al., Arcaine Blocks N-Methyl-D-Aspartate Receptor Responses by an Open Channel Mechanism:

5 Whole-Cell and Single-Channel Recording Studies in Cultured Hippocampal Neurons. *Molec. Pharmacol.* 41: 727, 1992; Rock and Macdonald, Spermine and Related Polyamines Produce a Voltage-Dependent Reduction of NMDA Receptor Single-Channel Conductance. *Molec. Pharmacol.* 10 42: 157, 1992).

Recent studies have demonstrated the molecular diversity of glutamate receptors (reviewed by Nakanishi, Molecular Diversity of Glutamate Receptors and Implications for Brain Function. *Science* 258: 597, 15 1992). At least five distinct NMDA receptor subunits (NMDAR1 and NMDAR2A through NMDAR2D), each encoded by a distinct gene, have been identified to date. Also, in NMDAR1, alternative splicing gives rise to at least six additional isoforms. It appears that NMDAR1 is a 20 necessary subunit, and that combination of NMDAR1 with different members of NMDAR2 forms the fully functional NMDA receptor-ionophore complex. The NMDA receptor-ionophore complex, thus, can be defined as a hetero-oligomeric structure composed of at least NMDAR1 25 and NMDAR2 subunits; the existence of additional, as yet undiscovered, subunits is not excluded by this definition. NMDAR1 has been shown to possess binding sites for glutamate, glycine,  $Mg^{2+}$ , MK-801, and  $Zn^{2+}$ . The binding sites for sigma ligands and polyamines have not 30 yet been localized on NMDA receptor subunits, although ifenprodil recently has been reported to be more potent

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at the NMDAR2B subunit than at the NMDAR2A subunit  
(Williams, Ifenprodil discriminates subtypes of the  
N-methyl-D-aspartate receptor: selectivity and  
mechanisms at recombinant heteromeric receptors. Mol.  
5 Pharmacol. 44: 851, 1993).

Several distinct subtypes of AMPA and kainate  
receptors have been cloned as well (reviewed by  
Nakanishi, Molecular diversity of glutamate receptors  
and implications for brain function. Science 258: 597,  
10 1992). Of particular relevance are the AMPA receptors  
designated GluR1, GluR2, GluR3, and GluR4 (also termed  
GluRA through GluRD), each of which exists in one of two  
forms, termed flip and flop, which arise by RNA  
alternative splicing. GluR1, GluR3 and GluR4, when  
15 expressed as homomeric or heteromeric receptors, are  
permeable to  $\text{Ca}^{2+}$ , and are therefore examples of  
receptor-operated  $\text{Ca}^{2+}$  channels. Expression of GluR2  
alone or in combination with the other subunits gives  
rise to a receptor which is largely impermeable to  $\text{Ca}^{2+}$ .  
20 As most native AMPA receptors studied *in situ* are not  
 $\text{Ca}^{2+}$ -permeable (discussed above), it is believed that  
such receptors *in situ* possess at least one GluR2  
subunit.

Furthermore, it is hypothesized that the GluR2  
25 subunit is functionally distinct by virtue of the fact  
that it contains an arginine residue within the putative  
pore-forming transmembrane region II; GluR1, GluR3 and  
GluR4 all contain a glutamine residue in this critical  
region (termed the Q/R site, where Q and R are the  
30 single letter designations for glutamine and arginine,  
respectively). The activity of the AMPA receptor is

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regulated by a number of modulatory sites that can be targeted by selective antagonists (Honore et al., Quinoxalinediones: potent competitive non-NMDA glutamate receptor antagonists. *Science* 241: 701, 1988; Donevan and Rogawski, GYKI 52466, a 2,3-benzodiazepine, is a highly selective, noncompetitive antagonist of AMPA/kainate receptor responses. *Neuron* 10: 51, 1993). Competitive antagonists such as NBQX act at the glutamate binding site, whereas compounds such as GYKI 52466 appear to act noncompetitively at an associated allosteric site.

Compounds that act as competitive or noncompetitive antagonists at the NMDA receptor are said to be effective in preventing neuronal cell death in various in vitro neurotoxicity assays (Meldrum and Garthwaite, Excitatory amino acid neurotoxicity and neurodegenerative disease. *Trends Pharmacol. Sci.* 11: 379, 1990) and in in vivo models of stroke (Scatton, Therapeutic potential of NMDA receptor antagonists in ischemic cerebrovascular disease in *Drug Strategies in the Prevention and Treatment of Stroke*, IBC Technical Services Ltd., 1990). Such compounds are also effective anticonvulsants (Meldrum, Excitatory amino acid neurotransmission in epilepsy and anticonvulsant therapy in *Excitatory Amino Acids*. Meldrum, Moroni, Simon, and Woods (Eds.), New York: Raven Press, p. 655, 1991), anxiolytics (Wiley and Balster, Preclinical evaluation of N-methyl-D-aspartate antagonists for antianxiety effects: A review. In: *Multiple Sigma and PCP Receptor Ligands: Mechanisms for Neuromodulation and Neuroprotection?* NPP Books, Ann Arbor, Michigan, pp.

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801-815, 1992), and analgesics (Dickenson, A cure for  
wind-up: NMDA receptor antagonists as potential  
analgesics. *Trends Pharmacol. Sci.* 11: 307, 1990), and  
certain NMDA receptor antagonists may lessen dementia  
5 associated with Alzheimer's Disease (Hughes, Merz' novel  
approach to the treatment of dementia. *Script No.* 1666:  
24, 1991).

Similarly, AMPA receptor antagonists have come  
under intense scrutiny as potential therapeutic agents  
10 for the treatment of such neurological disorders and  
diseases. AMPA receptor antagonists have been shown to  
possess neuroprotectant (Fisher and Bogousslavsky,  
Evolving toward effective therapy for acute ischemic  
stroke. *J. Amer. Med. Assoc.* 270: 360, 1993) and  
15 anticonvulsant (Yamaguchi et al., Anticonvulsant  
activity of AMPA/kainate antagonists: comparison of GYKI  
52466 and NBQX in maximal electroshock and  
chemoconvulsant seizure models. *Epilepsy Res.* 15: 179,  
1993) activity in animal models of ischemic stroke and  
20 epilepsy, respectively.

The nicotinic cholinergic receptor present in  
the mammalian CNS is another example of a  
receptor-operated  $Ca^{2+}$  channel (Deneris et al.,  
Pharmacological and functional diversity of neuronal  
25 nicotinic acetylcholine receptors. *Trends Pharmacol.*  
*Sci.* 12: 34, 1991). Several distinct receptor subunits  
have been cloned, and these subunits can be expressed,  
in *Xenopus* oocytes for example, to form functional  
receptors with their associated cation channels. It is  
30 hypothesized that such receptor-ionophore complexes are  
heteropentameric structures. The possible role of

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nicotinic receptor-operated  $Ca^{2+}$  channels in the pathology of neurological disorders and diseases such as ischemic stroke, epilepsy and neurodegenerative diseases has been largely unexplored.

5                   It has been demonstrated previously that certain spider and wasp venoms contain arylalkylamine toxins (also called polyamine toxins, arylamine toxins, acylpolyamine toxins or polyamine amide toxins) with activity against glutamate receptors in the mammalian  
10 CNS (for reviews see Jackson and Usherwood, Spider toxins as tools for dissecting elements of excitatory amino acid transmission. *Trends Neurosci.* 11: 278, 1988; Jackson and Parks, Spider Toxins: Recent Applications In Neurobiology. *Annu. Rev. Neurosci.* 12: 405, 1989; Saccomano et al., Polyamine spider toxins: Unique pharmacological tools. *Annu. Rep. Med. Chem.* 24: 287, 1989; Usherwood and Blagbrough, Spider Toxins Affecting Glutamate Receptors: Polyamines in Therapeutic Neurochemistry. *Pharmacol. Therap.* 52: 245, 1991;  
15 Kawai, Neuroactive Toxins of Spider Venoms. *J. Toxicol. Toxin Rev.* 10: 131, 1991). Arylalkylamine toxins were initially reported to be selective antagonists of the AMPA/kainate subtypes of glutamate receptors in the mammalian CNS (Kawai et al., Effect of a spider toxin on  
20 glutaminergic synapses in the mammalian brain. *Biomed. Res.* 3: 353, 1982; Saito et al., Spider Toxin (JSTX) blocks glutamate synapse in hippocampal pyramidal neurons. *Brain Res.* 346: 397, 1985; Saito et al., Effects of a spider toxin (JSTX) on hippocampal CA1  
25 neurons in vitro. *Brain Res.* 481: 16, 1989; Akaike et al., Spider toxin blocks excitatory amino acid responses



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in isolated hippocampal pyramidal neurons. *Neurosci. Lett.* 79: 326, 1987; Ashe et al., Argiotoxin-636 blocks excitatory synaptic transmission in rat hippocampal CA1 pyramidal neurons. *Brain Res.* 480: 234, 1989; Jones et al., Philanthotoxin blocks quisqualate-induced, AMPA-induced and kainate-induced, but not NMDA-induced excitation of rat brainstem neurones in vivo. *Br. J. Pharmacol.* 101: 968, 1990). Subsequent studies have demonstrated that while certain arylalkylamine toxins are both nonpotent and nonselective at various glutamate receptors, other arylalkylamines are both very potent and selective at antagonizing responses mediated by NMDA receptor activation in the mammalian CNS (Mueller et al., Effects of polyamine spider toxins on NMDA receptor-mediated transmission in rat hippocampus in vitro. *Soc. Neurosci. Abst.* 15: 945, 1989; Mueller et al., Arylamine spider toxins antagonize NMDA receptor-mediated synaptic transmission in rat hippocampal slices. *Synapse* 9: 244, 1991; Parks et al., Polyamine spider toxins block NMDA receptor-mediated increases in cytosolic calcium in cerebellar granule neurons. *Soc. Neurosci. Abst.* 15: 1169, 1989; Parks et al., Arylamine toxins from funnel-web spider (*Agelenopsis aperta*) venom antagonize N-methyl-D-aspartate receptor function in mammalian brain. *J. Biol. Chem.* 266: 21523, 1991; Priestley et al., Antagonism of responses to excitatory amino acids on rat cortical neurones by the spider toxin, argiotoxin-636. *Br. J. Pharmacol.* 97: 1315, 1989; Draguhn et al., Argiotoxin-636 inhibits NMDA-activated ion channels expressed in *Xenopus* oocytes. *Neurosci. Lett.* 132: 187,

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1991; Kiskin et al., A highly potent and selective  
N-methyl-D-aspartate receptor antagonist from the venom  
of the *Agelenopsis aperta* spider. *Neuroscience* 51: 11,  
1992; Brackley et al., Selective antagonism of native  
5 and cloned kainate and NMDA receptors by  
polyamine-containing toxins. *J. Pharmacol. Exptl.*  
*Therap.* 266: 1573, 1993; Williams, Effects of  
*Agelenopsis aperta* toxins on the N-methyl-D-aspartate  
receptor: Polyamine-like and high-affinity antagonist  
10 actions. *J. Pharmacol. Exptl. Therap.* 266: 231, 1993).  
Inhibition of nicotinic cholinergic receptors by the  
arylalkylamine toxin philanthotoxin has also been  
reported (Rozental et al., Allosteric inhibition of  
nicotinic acetylcholine receptors of vertebrates and  
15 insects by philanthotoxin. *J. Pharmacol. Exptl. Therap.*  
249: 123, 1989).

Parks et al. (Arylamine toxins from funnel-web  
spider (*Agelenopsis aperta*) venom antagonize  
N-methyl-D-aspartate receptor function in mammalian  
20 brain. *J. Biol. Chem.* 266: 21523, 1991), describe  
arylalkylamine spider toxins ( $\alpha$ -agatoxins) which  
antagonize NMDA receptor function in mammalian brain.  
The authors discuss the mechanism of action of  
arylalkylamine toxins, and indicate that an NMDA  
25 receptor-operated ion channel is the probable site of  
action of the  $\alpha$ -agatoxins, and most probably other  
spider venom arylalkylamines. They state:

30 The discovery that endogenous  
polyamines in the vertebrate brain  
modulate the function of NMDA  
receptors suggests that the  
arylamine toxins may produce their

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antagonism via a polyamine-binding site on glutamate receptors. Brackley et al. studied the effects of spermine and philanthotoxin 433 on the responses evoked by application of excitatory amino acids in *Xenopus* oocytes injected with mRNA from rat or chick brain. These authors reported that, at concentrations below those that antagonize glutamate receptor function, both spermine and philanthotoxin potentiate the effects of excitatory amino acids and some other neurotransmitters. On the basis of these and other data, Brackley et al. concluded that the arylamine toxins may, by binding nonspecifically to the membranes of excitable cells, reduce membrane fluidity and alter receptor function. The validity of this intriguing idea for NMDA receptor function is not well supported by two recent binding studies. Reynolds reported that argiotoxin 636 inhibits the binding of [<sup>3</sup>H]MK-801 to rat brain membranes in a manner that is insensitive to glutamate, glycine, or spermidine. This author concluded that argiotoxin 636 exerts a novel inhibitory effect on the NMDA receptor complex by binding to one of the Mg<sup>2+</sup> sites located within the NMDA-gated ion channel. Binding data reported by Williams et al. also support the conclusion that argiotoxin 636 does not act primarily at the polyamine modulatory site on the NMDA receptor, but rather acts directly to produce an activity-dependent block of the ion channel. It is already known that compounds such as phencyclidine and ketamine can block

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the ion channels associated with both arthropod muscle glutamate receptors and mammalian NMDA receptors. Thus, it seems possible that vertebrate and invertebrate glutamate receptors share additional binding sites for allosteric modulators of receptor function, perhaps related to divalent cation-binding sites. Clearly, considerable additional work will be needed to determine if the arylamines define such a novel regulatory site.

Usherwood and Blagbrough (Spider Toxins Affecting Glutamate Receptors: Polyamines in Therapeutic Neurochemistry. *Pharmacol. Therap.* 52: 245, 1991) describe a proposed intracellular binding site for arylalkylamine toxins (polyamine amide toxins) located within the membrane potential field referred to as the QUIS-R channel selectivity filter. The authors postulate that the binding site for polyamine amide toxins may occur close to the internal entrance of the channel gated by the QUIS-R of locust muscle. The authors also note that one such toxin, argiotoxin-636, selectively antagonizes the NMDA receptor in cultured rat cortical neurons.

Gullak et al. (CNS binding sites of the novel NMDA antagonist Arg-636. *Soc. Neurosci. Abst.* 15: 1168, 1989), describe argiotoxin-636 (Arg-636) as a polyamine (arylalkylamine) toxin component of a spider venom. This toxin is said to block NMDA-induced elevation of cGMP in a noncompetitive fashion. The authors state that:

[<sup>125</sup>I]Arg-636 bound to rat forebrain

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5 membranes with  $K_d$  and  $B_{max}$  values of  
11.25  $\mu$ M and 28.95 pmol/mg protein  
(80% specific). The ability of  
other known polyamines and recently  
10 discovered polyamines from  
*Agelenopsis aperta* to inhibit  
binding paralleled neuroactivity as  
functional NMDA antagonists. No  
other compounds tested were able to  
block specific binding.

The authors then stated that polyamines  
(arylalkylamines) may antagonize responses to NMDA by  
interacting with membrane ion channels.

Seymour and Mena (*In vivo* NMDA antagonist  
15 activity of the polyamine spider venom component,  
argitoxin-636. *Soc. Neurosci. Abst.* 15: 1168, 1989)  
describe studies that are said to show that  
argitoxin-636 does not significantly affect locomotor  
activity at doses that are effective against audiogenic  
20 seizures in DBA/2 mice, and that it significantly  
antagonizes NMDA-induced seizures with a minimal  
effective dose of 32 mg/kg given subcutaneously (s.c.).

Herold and Yaksh (Anesthesia and muscle  
relaxation with intrathecal injections of AR636 and  
25 AG489, two acylpolyamine spider toxins, in rats.  
*Anesthesiology* 77: 507, 1992) describe studies that are  
said to show that the arylalkylamine argitoxin-636  
(AR636), but not agatoxin-489 (AG489), produces muscle  
relaxation and anesthesia following intrathecal  
30 administration in rats.

Williams (Effects of *Agelenopsis aperta* toxins  
on the N-methyl-D-aspartate receptor: Polyamine-like and  
high-affinity antagonist actions, *J. Pharmacol. Exptl.*

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Therap. 266: 231, 1993) reports that the  $\alpha$ -agatoxins (arylalkylamines) Agel-489 and Agel-505 enhance the binding of [ $^3$ H]MK-801 to NMDA receptors on membranes prepared from rat brain by an action at the stimulatory polyamine receptor; polyamine receptor agonists occluded the stimulatory effects of Agel-489 and Agel-505 and polyamine receptor antagonists inhibited the stimulatory effect of Agel-505. Higher concentrations of Agel-489 and Agel-505, and argiotoxin-636 at all concentrations tested, had inhibitory effects on the binding of [ $^3$ H]MK-801. In *Xenopus* oocytes voltage-clamped at -70 mV, Agel-505 inhibited responses to NMDA with an  $IC_{50}$  of 13 nM; this effect of Agel-505 occurred at concentrations approximately 10,000-fold lower than those that affected [ $^3$ H]MK-801 binding. Responses to kainate were inhibited only 11% by 30 nM Agel-505. The antagonism of NMDA-induced currents by Agel-505 was strongly voltage-dependent, consistent with an open-channel blocking effect of the toxin. Williams states:

Although  $\alpha$ -agatoxins can interact at the positive allosteric polyamine site on the NMDA receptor, stimulatory effects produced by this interaction may be masked in functional assays due to a separate action of the toxins as high-affinity, noncompetitive antagonists of the receptor.

Brackley et al. (Selective antagonism of native and cloned kainate and NMDA receptors by polyamine-containing toxins, *J. Pharmacol. Exp. Therap.* 266: 1573, 1993) report that the polyamine-containing

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toxins (arylalkylamines) philanthotoxin-343 (PhTX-343) and argiotoxin-636 (Arg-636) produce reversible, noncompetitive, partly voltage-dependent antagonism of kainate- and NMDA-induced currents in *Xenopus* oocytes injected with rat brain RNA. Arg-636 was demonstrated to be selective for NMDA-induced responses ( $IC_{50} = 0.04 \mu M$ ) compared to kainate-induced responses ( $IC_{50} = 0.07 \mu M$ ), while PhTX-343 was selective for kainate-induced responses ( $IC_{50} = 0.12 \mu M$ ) compared to NMDA-induced responses ( $IC_{50} = 2.5 \mu M$ ). Arg-636 more potently antagonized responses to NMDA in *Xenopus* oocytes expressing cloned NMDAR1 subunits ( $IC_{50} = 0.09 \mu M$ ) than responses to kainate in oocytes expressing either cloned GluR1 ( $IC_{50} = 3.4 \mu M$ ) or GluR1+GluR2 subunits ( $IC_{50} = 300 \mu M$ ). PhTX-343, on the other hand, was equipotent at antagonizing NMDAR1 ( $IC_{50} = 2.19 \mu M$ ) and GluR1 ( $IC_{50} = 2.8 \mu M$ ), but much less potent against GluR1+GluR2 subunits ( $IC_{50} = 270 \mu M$ ).

Raditsch et al. (Subunit-specific block of cloned NMDA receptors by argiotoxin-636. *FEBS Lett.* 324: 63, 1993) report that Arg-636 more potently antagonizes responses in *Xenopus* oocytes expressing NMDAR1+NMDAR2A subunits ( $IC_{50} = 9 nM$ ) or NMDAR1+NMDAR2B subunits ( $IC_{50} = 2.5 nM$ ) than NMDAR1+NMDAR2C subunits ( $IC_{50} = 460 nM$ ), even though all of the receptor subunits contain an asparagine residue in the putative pore-forming transmembrane region II (the Q/R site, as discussed above). The authors state that the large difference in Arg-636 sensitivity between NMDAR1+NMDAR2A and NMDAR1+NMDAR2C channels "must be conferred by other structural determinants."

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Herlitz et al. (Argiotoxin detects molecular differences in AMPA receptor channels. *Neuron* 10: 1131, 1993) report that Arg-636 antagonizes subtypes of AMPA receptors in a voltage- and use-dependent manner  
5 consistent with open-channel blockade. Arg-636 potentially antagonizes  $\text{Ca}^{2+}$ -permeable AMPA receptors comprised of GluRAi ( $K_i = 0.35 \mu\text{M}$ ), GluRCi ( $K_i = 0.23 \mu\text{M}$ ), or GluRDi subunits ( $K_i = 0.43 \mu\text{M}$ ), while being essentially ineffective against  $\text{Ca}^{2+}$ -impermeable GluRBi subunits at  
10 concentrations up to  $10 \mu\text{M}$ .

Other data reported by these investigators strongly suggest that the Q/R site in the putative pore-forming transmembrane region II is of primary importance in determining Arg-636 potency and  $\text{Ca}^{2+}$   
15 permeability.

Blaschke et al. (A single amino acid determines the subunit-specific spider toxin block of  $\alpha$ -amino-3-hydroxy-5-methylisoxazole-4-propionate/kainate receptor channels. *Proc. Natl. Acad. Sci. USA* 90: 6528,  
20 1993) report that the arylalkylamine JSTX-3 potentially antagonizes responses to kainate in *Xenopus* oocytes expressing GluR1 ( $\text{IC}_{50} = 0.04 \mu\text{M}$ ) or GluR3 ( $\text{IC}_{50} = 0.03 \mu\text{M}$ ) subunits, but that expressed receptors in which a GluR2 subunit is present are essentially unaffected by  
25 the toxin. Site-directed mutagenesis studies strongly implicate the Q/R site as the primary site influencing toxin potency.

Nakanishi et al. (Bioorganic studies of transmitter receptors with philanthotoxin analogs. *Pure Appl. Chem.*, in press) have synthesized a number of  
30 highly potent photoaffinity labeled philanthotoxin



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(PhTX) analogs. Such analogs have been studied on expressed nicotinic cholinergic receptors as a model system for receptor-operated calcium channels. These investigators suggest that these PhTX analogs block the ion channel with the hydrophobic headpiece of the toxin binding to a site near the cytoplasmic surface while the polyamine tail extends into the ion channel from the cytoplasmic side.

#### Summary of the Invention

Applicant has examined the structural diversity and biological activity of arylalkylamines (sometimes referred to as arylamine toxins, polyamine toxins, acylpolyamine toxins or polyamine amide toxins) in spider and wasp venoms, and determined that some of the arylalkylamines present in these venoms act as potent noncompetitive antagonists of glutamate receptor-operated  $\text{Ca}^{2+}$  channels in the mammalian CNS. Although these arylalkylamine compounds contain within their structure a polyamine moiety, they are unlike other known simple polyamines in possessing extremely potent and specific effects on certain types of receptor-operated  $\text{Ca}^{2+}$  channels.

Using native arylalkylamines as lead structures, a number of analogs were synthesized and tested. Initial findings on arylalkylamines isolated and purified from venom were confirmed utilizing synthetic arylalkylamines. These compounds are small molecules (mol. wt. <800) with demonstrated efficacy in *in vivo* models of stroke and epilepsy. The NMDA receptor-ionophore complex was used as a model of

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receptor-operated  $\text{Ca}^{2+}$  channels. Selected  
arylalkylamines were shown to block NMDA  
receptor-mediated responses by a novel mechanism.  
Moreover, the unique behavioral pharmacological profile  
5 of these compounds suggests that they are unlikely to  
cause the PCP-like psychotomimetic activity and  
cognitive deficits that characterize other inhibitors of  
the NMDA receptor. Finally, the arylalkylamines are  
unique amongst NMDA receptor antagonists in that they  
10 are able to antagonize certain subtypes of cloned and  
expressed AMPA receptors, namely, those permeable to  
 $\text{Ca}^{2+}$ . The arylalkylamines, therefore, are the only known  
class of compounds able to antagonize glutamate  
receptor-mediated increases in cytosolic  $\text{Ca}^{2+}$  regardless  
15 of the pharmacological definition of receptor subtype.  
Additionally, the arylalkylamines inhibit another  
receptor-operated  $\text{Ca}^{2+}$  channel, the nicotinic cholinergic  
receptor. Given that excessive and prolonged increases  
in cytosolic  $\text{Ca}^{2+}$  have been implicated in the etiology of  
20 several neurological disorders and diseases, such  
arylalkylamines are valuable small molecule leads for  
the development of novel therapeutics for various  
neurological disorders and diseases.

Applicant has determined that the selected  
25 arylalkylamines bind with high affinity at a novel site  
on the NMDA receptor-ionophore complex which has  
heretofore been unidentified, and that said  
arylalkylamines do not bind with high affinity at any of  
the known sites (glutamate binding site, glycine binding  
30 site, MK-801 binding site,  $\text{Mg}^{2+}$  binding site,  $\text{Zn}^{2+}$  binding  
site, polyamine binding site, sigma binding site) on

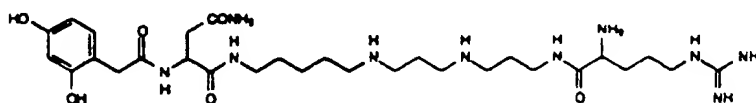
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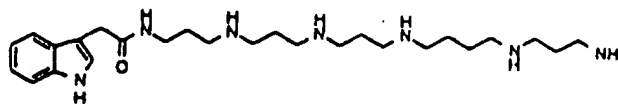
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said NMDA receptor-ionophore complex. This determination has allowed applicant to develop methods and protocols by which useful compounds can be identified which provide both therapeutically useful compounds and lead compounds for the development of other therapeutically useful compounds. These compounds can be identified by screening for compounds that bind at this novel arylalkylamine binding site, and by determining whether such a compound has the required biological, pharmacological and physiological properties.

The method includes the step of identifying a compound which binds to the receptor-operated  $\text{Ca}^{2+}$  channel at that site bound by the arylalkylamine compounds referred to herein as Compound 1, Compound 2 or Compound 3, and having the structures shown below.



Compound 1

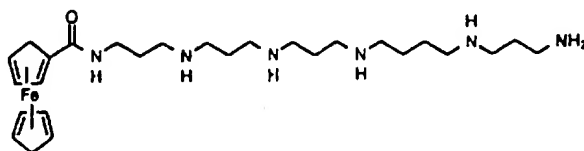


Compound 2

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Compound 3

By "therapeutically useful compound" is meant a compound that is potentially useful in the treatment of a disorder or disease state. A compound uncovered by the screening method is characterized as having potential therapeutic utility in treatment because clinical tests have not yet been conducted to determine actual therapeutic utility.

By "neurological disorder or disease" is meant a disorder or disease of the nervous system including, but not limited to, global and focal ischemic and hemorrhagic stroke, head trauma, spinal cord injury, spinal cord ischemia, ischemia- or hypoxia-induced nerve cell damage, hypoxia-induced nerve cell damage as in cardiac arrest or neonatal distress, epilepsy, anxiety, neuropsychiatric or cognitive deficits due to ischemia or hypoxia such as those that frequently occur as a consequence of cardiac surgery under cardiopulmonary bypass, and neurodegenerative disease. Also meant by "neurological disorder or disease" are those disease states and conditions in which a neuroprotectant, anticonvulsant, anxiolytic, analgesic, muscle relaxant and/or adjunct in general anesthesia may be indicated, useful, recommended or prescribed.

By "neurodegenerative disease" is meant diseases including, but not limited to, Alzheimer's Disease, Huntington's Disease, Parkinson's Disease, and

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amyotrophic lateral sclerosis (ALS).

By "neuroprotectant" is meant a compound capable of preventing the neuronal damage or death associated with a neurological disorder or disease.

5 By "anticonvulsant" is meant a compound capable of reducing convulsions produced by conditions such as simple partial seizures, complex partial seizures, status epilepticus, and trauma-induced seizures such as occur following head injury, including  
10 head surgery.

By "anxiolytic" is meant a compound capable of relieving the feelings of apprehension, uncertainty and fear that are characteristic of anxiety.

By "analgesic" is meant a compound capable of  
15 relieving pain by altering perception of nociceptive stimuli without producing anesthesia or loss of consciousness.

By "muscle relaxant" is meant a compound that reduces muscular tension.

20 By "adjunct in general anesthesia" is meant a compound useful in conjunction with anesthetic agents in producing the loss of ability to perceive pain associated with the loss of consciousness.

By "potent" or "active" is meant that the  
25 compound has activity at receptor-operated calcium channels, including NMDA receptors,  $\text{Ca}^{2+}$ -permeable AMPA receptors, and nicotinic cholinergic receptors, with an  $\text{IC}_{50}$  value less than 10  $\mu\text{M}$ , more preferably less than 100 nM, and even more preferably less than 1 nM.

30 By "selective" is meant that the compound is

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potent at receptor-operated calcium channels as defined above, but is less potent by greater than 10-fold, more preferably 50-fold, and even more preferably 100-fold, at other neurotransmitter receptors, neurotransmitter  
5 receptor-operated ion channels, or voltage-dependent ion channels.

By "biochemical and electrophysiological assays of receptor-operated calcium channel function" is meant assays designed to detect by biochemical or  
10 electrophysiological means the functional activity of receptor-operated calcium channels. Examples of such assays include, but are not limited to, the fura-2 fluorimetric assay for cytosolic calcium in cultured rat cerebellar granule cells (see Example 1 and Example 2),  
15 patch clamp electrophysiological assays (see Example 3 and Example 27), rat hippocampal slice synaptic transmission assays (see Example 5), radioligand binding assays (see Example 4, Example 24, Example 25, and Example 26), and in vitro neuroprotectant assays (see  
20 Example 6).

By "efficacy" is meant that a statistically significant level of the desired activity is detectable with a chosen compound; by "significant" is meant a statistical significance at the  $p < 0.05$  level.

25 By "neuroprotectant activity" is meant efficacy in treatment of neurological disorders or diseases including, but not limited to, global and focal ischemic and hemorrhagic stroke, head trauma, spinal cord injury, spinal cord ischemia, ischemia- or hypoxia-  
30 induced nerve cell damage, hypoxia-induced nerve cell damage as in cardiac arrest or neonatal distress,

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neuropsychiatric or cognitive deficits due to ischemia or hypoxia such as those that frequently occur as a consequence of cardiac surgery under cardiopulmonary bypass, and neurodegenerative diseases such as

5 Alzheimer's Disease, Huntington's Disease, Parkinson's Disease, and amyotrophic lateral sclerosis (ALS) (see Examples 7 and 8, below).

By "anticonvulsant activity" is meant efficacy in reducing convulsions produced by conditions such as

10 simple partial seizures, complex partial seizures, status epilepticus, and trauma-induced seizures such as occur following head injury, including head surgery (see Examples 9 and 10, below).

By "anxiolytic activity" is meant that a

15 compound reduces the feelings of apprehension, uncertainty and fear that are characteristic of anxiety.

By "analgesic activity" is meant that a compound produces the absence of pain in response to a stimulus that would normally be painful. Such activity

20 would be useful in clinical conditions of acute and chronic pain including, but not limited to the following: preemptive preoperative analgesia; peripheral neuropathies such as occur with diabetes mellitus and multiple sclerosis; phantom limb pain; causalgia;

25 neuralgias such as occur with herpes zoster; central pain such as that seen with spinal cord lesions; hyperalgesia; and allodynia.

By "causalgia" is meant a painful disorder associated with injury of peripheral nerves.

30 By "neuralgia" is meant pain in the distribution of a nerve or nerves.

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By "central pain" is meant pain associated with a lesion of the central nervous system.

By "hyperalgesia" is meant an increased response to a stimulus that is normally painful.

5 By "allodynia" is meant pain due to a stimulus that does not normally provoke pain (see Examples 11 through 14, below).

By "induction of long-term potentiation in rat hippocampal slices" is meant the ability of tetanic  
10 electrical stimulation of afferent Schaffer collateral fibers to elicit long-term increases in the strength of synaptic transmission at the Schaffer collateral-CA1 pyramidal cell pathway in rat hippocampal slices maintained in vitro (see Example 19).

15 By "therapeutic dose" is meant an amount of a compound that relieves to some extent one or more symptoms of the disease or condition of the patient. Additionally, by "therapeutic dose" is meant an amount that returns to normal, either partially or completely,  
20 physiological or biochemical parameters associated with or causative of the disease or condition. Generally, it is an amount between about 1 nmole and 1  $\mu$ mole of the compound, dependent on its  $EC_{50}$  ( $IC_{50}$  in the case of an antagonist) and on the age, size, and disease associated  
25 with the patient.

By "impair cognition" is meant the ability to impair the acquisition of memory or the performance of a learned task (see Example 20). Also by "impair  
cognition" is meant the ability to interfere with  
30 normal rational thought processes and reasoning.

By "disrupt motor function" is meant the



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ability to significantly alter locomotor activity (see Example 15) or elicit significant ataxia, loss of the righting reflex, sedation or muscle relaxation (see Example 16).

5           By "locomotor activity" is meant the ability to perform normal ambulatory movements.

          By "loss of the righting reflex" is meant the ability of an animal, typically a rodent, to right itself after being placed in a supine position.

10           By "neuronal vacuolization" is meant the production of vacuoles in neurons of the cingulate cortex or retrosplenial cortex (see Example 18).

          By "cardiovascular activity " is meant the ability to elicit significant changes in parameters  
15 including, but not limited to, mean arterial blood pressure and heart rate (see Examples 21 and 22).

          By "hyperexcitability" is meant an enhanced susceptibility to an excitatory stimulus. Hyperexcitability is often manifested as a significant  
20 increase in locomotor activity in rodents administered a drug (see Example 15).

          By "sedation" is meant a calmativ effect, or the allaying of activity and excitement. Sedation is often manifested as a significant decrease in locomotor  
25 activity in rodents administered a drug (see Example 15).

          By "PCP-like abuse potential" is meant the potential of a drug to be wrongfully used, as in the recreational use of PCP (i.e., "angel dust") by man. It  
30 is believed that PCP-like abuse potential can be predicted by the ability of a drug to generalize to PCP

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in rodents trained to discriminate PCP from saline (see Example 17.)

By "generalization to PCP" is meant that a compound is perceived as being PCP in rodents trained to discriminate PCP from saline (see Example 17).

By "PCP-like psychotomimetic activity" is meant the ability of a drug to elicit in man a behavioral syndrome resembling acute psychosis, including visual hallucinations, paranoia, agitation, and confusion. It is believed that PCP-like psychotomimetic activity can be predicted in rodents by the ability of a drug to produce PCP-like stereotypic behaviors including ataxia, head weaving, hyperexcitability, and generalization to PCP in rodents trained to discriminate PCP from saline (see Example 15, Example 16, and Example 17).

By "ataxia" is meant a deficit in muscular coordination.

By "head weaving" is meant the stereotypic behavior elicited in rodents by PCP in which the head is repeatedly moved slowly and broadly from side to side.

By "pharmaceutical composition" is meant a therapeutically effective amount of a compound of the present invention in a pharmaceutically acceptable carrier, i.e., a formulation to which the compound can be added to dissolve or otherwise facilitate administration of the compound. Examples of pharmaceutically acceptable carriers include water, saline, and physiologically buffered saline. Such a pharmaceutical composition is provided in a suitable dose. Such compositions are generally those which are

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approved for use in treatment of a specified disorder by the FDA or its equivalent in non-U.S. countries.

In a related aspect, the invention features a method for treating a neurological disease or disorder, comprising the step of administering a pharmaceutical composition comprising a compound which binds to a receptor-operated calcium channel at the site bound by one of the arylalkylamines Compound 1, Compound 2 and Compound 3, said compound being a potent and selective noncompetitive antagonist at such a receptor-operated calcium channel, and having one or more of the following pharmacological and physiological properties: efficacy in *in vitro* biochemical and electrophysiological assays of receptor-operated calcium channel function, *in vivo* anticonvulsant activity, *in vivo* neuroprotectant activity, *in vivo* anxiolytic activity, and *in vivo* analgesic activity; said compound also possessing one or more of the following pharmacological effects: the compound does not interfere with the induction of long-term potentiation in rat hippocampal slices, and, at a therapeutic dose, does not impair cognition, does not disrupt motor performance, does not produce neuronal vacuolization, has minimal cardiovascular activity, does not produce sedation or hyperexcitability, has minimal PCP-like abuse potential, and has minimal PCP-like psychotomimetic activity. By "minimal" is meant that any side effect of the drug is tolerated by an average individual, and thus that the drug can be used for therapy of the target disease. Such side effects are well known in the art and are routinely regarded by the FDA as minimal when it approves a drug for a target

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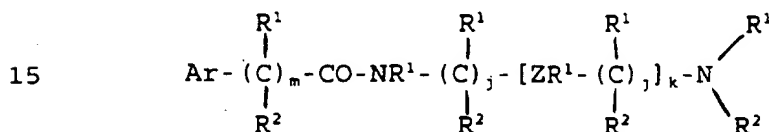
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disease.

Treatment involves the steps of first identifying a patient that suffers from a neurological disease or disorder by standard clinical methodology and then treating such a patient with a composition of the present invention.

In a further aspect, the invention features compounds useful for treating a patient having a neurological disease or disorder wherein said compound is a polyamine-type compound or an analog thereof (i.e., a polyheteroatomic molecule) having the formula



wherein Ar is an appropriately substituted aromatic ring, ring system or other hydrophobic entity; Ar can be an aromatic (e.g., carbocyclic aryl groups such as phenyl and bicyclic carbocyclic aryl ring systems such as naphthyl, 1,2,3,4-tetrahydronaphthyl, indanyl, and indenyl), heteroaromatic (e.g., indolyl, dihydroindolyl, quinolinyl and isoquinolinyl, and their respective 1,2,3,4-tetrahydro- and 2-oxo- derivatives), alicyclic (cycloaliphatic), or heteroalicyclic ring or ring system (mono-, bi-, or tricyclic), having 5- to 7-membered ring(s) optionally substituted with 1 to 5 substituents independently selected from lower alkyl of 1 to 5 carbon atoms, lower haloalkyl of 1 to 5 carbon atoms substituted with 1 to 7 halogen atoms, lower alkoxy of 1

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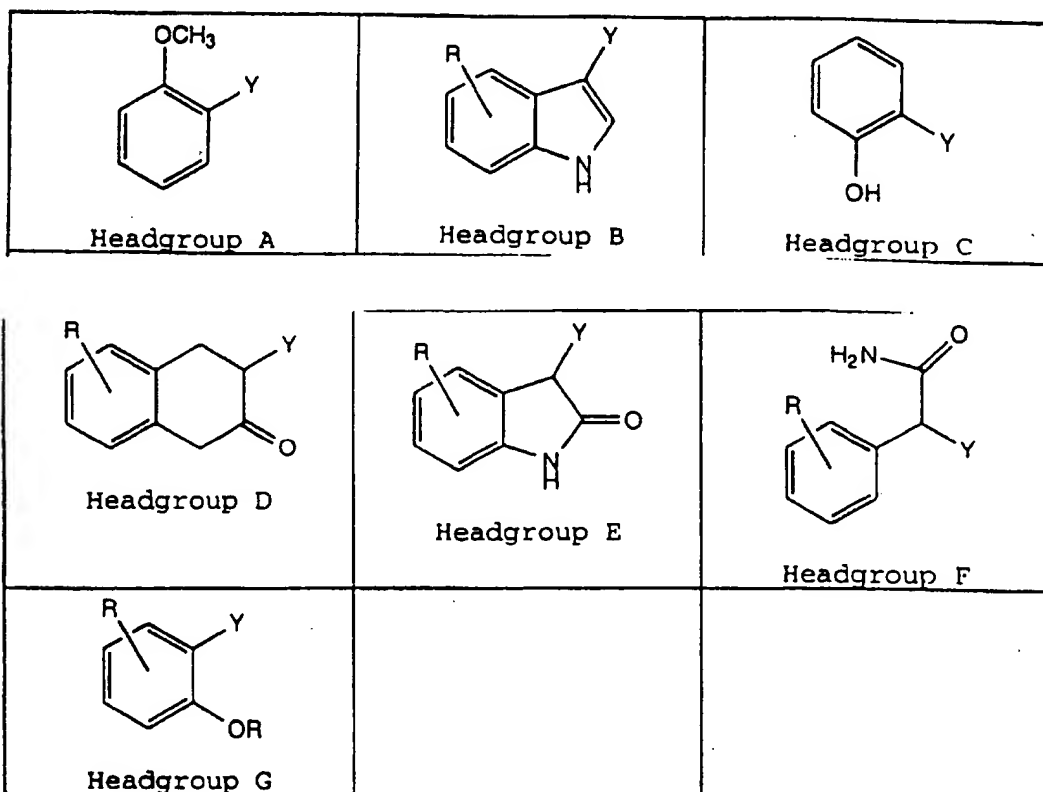
- to 5 carbon atoms, halogen, nitro, amino, lower alkylamino of 1 to 5 carbon atoms, amido, lower alkylamido of 1 to 5 carbon atoms, cyano, hydroxyl, sulfhydryl, lower acyl of 2 to 4 carbon atoms,
- 5 sulfonamido, lower alkylsulfonamido of 1 to 5 carbon atoms, lower alkylsulfoxide of 1 to 5 carbon atoms, lower hydroxyalkyl of 1 to 5 carbon atoms, lower alkylketo of 1 to 5 carbon atoms, or lower thioalkyl of 1 to 5 carbon atoms,
- 10 each m is an integer from 0 to 3, inclusive,  
each k is an integer from 1 to 10, inclusive,  
each j is the same or different and is an integer from 1 to 12, inclusive,  
each R<sup>1</sup> and R<sup>2</sup> independently is selected from the
- 15 group consisting of hydrogen, lower alkyl of 1 to 5 carbon atoms, lower alkylamino of 1 to 5 carbon atoms, lower alkylamido of 1 to 5 carbon atoms, lower mono-, di-, or trifluoroalkyl of 1 to 5 carbon atoms, hydroxy, amidino, guanidino, or typical common amino acid side
- 20 chain or with an associated carbon atom R<sup>1</sup> and R<sup>2</sup> taken together form a carbonyl, and  
each Z is selected from the group consisting of nitrogen, oxygen, sulfur, amido, sulfonamido, and carbon.

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Preferred aromatic headgroups include, but are not limited to, the following:

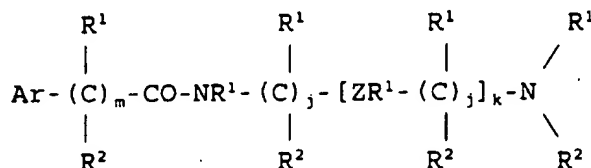


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where Y =

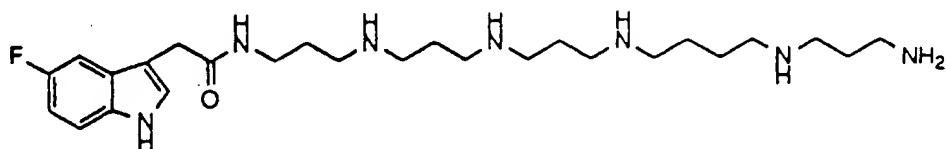


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Preferably the claims claiming a compound exclude known compounds whose chemical structures are enabled.

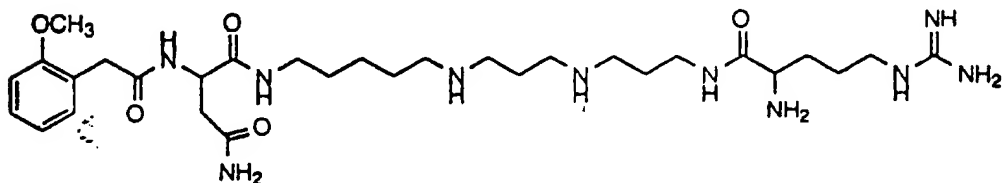
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In further preferred embodiments, the compound is selected from the group of Compounds 4 through 18, where such compounds have the formulae:

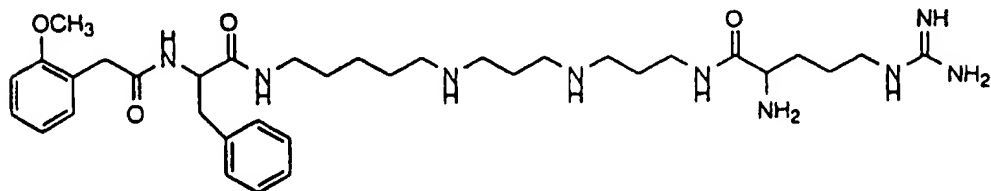


Compound 4

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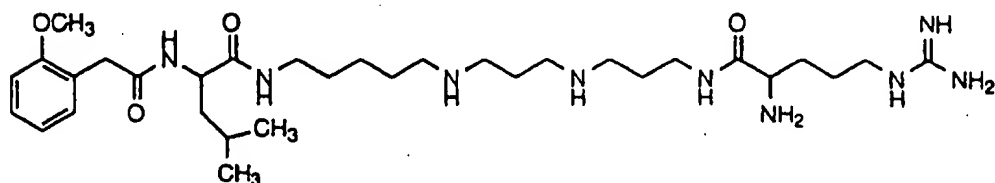


Compound 5



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Compound 6

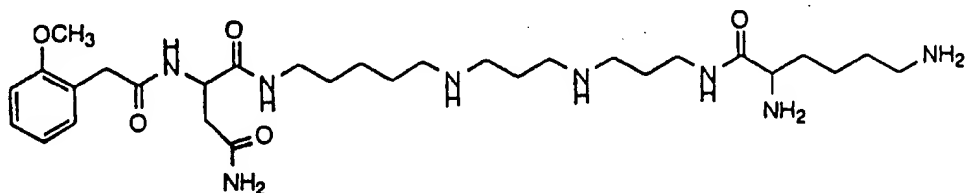


Compound 7

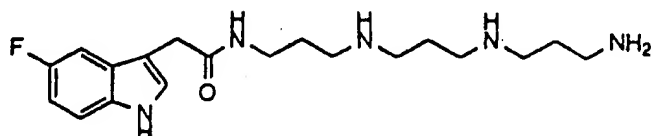
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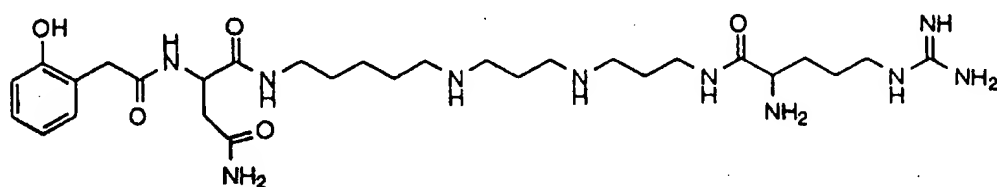


Compound 8

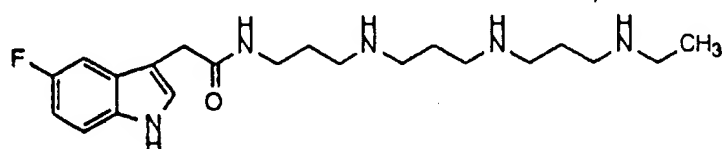


Compound 9

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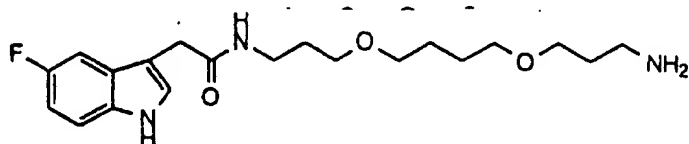


Compound 10

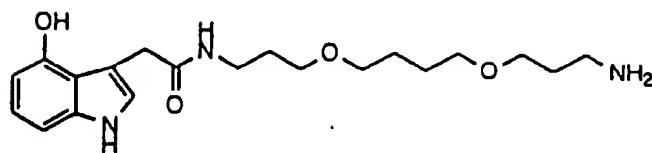


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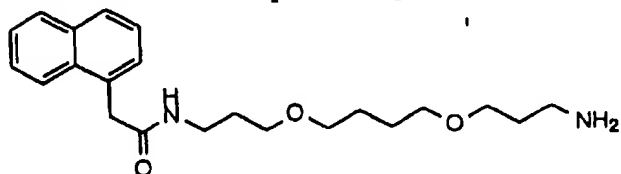
Compound 11



Compound 12



Compound 13



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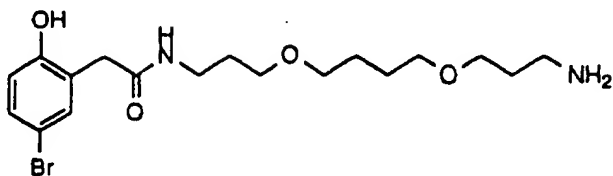
Compound 14



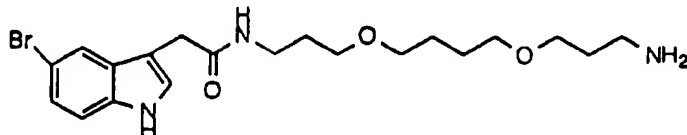
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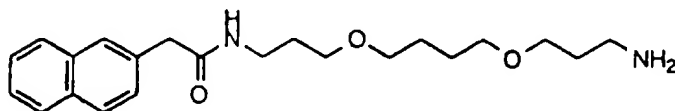


Compound 15

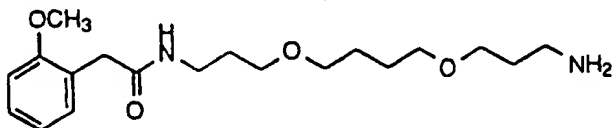


Compound 16

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Compound 17



Compound 18

Applicant has also determined (see Example 23 below) that simplified arylalkylamines (see below) are potent, noncompetitive antagonists of the NMDA receptor-ionophore complex. The simplified arylalkylamines are distinct from the arylalkylamines exemplified by Compounds 4-18 as described above. For example, such compounds bind to the site labeled by [<sup>3</sup>H]MK-801 at concentrations ranging approximately 1 to 400-fold higher than those which antagonize NMDA receptor-mediated function. Such simplified arylalkylamines possess one or more of the following additional biological properties: significant neuroprotectant activity, significant anticonvulsant

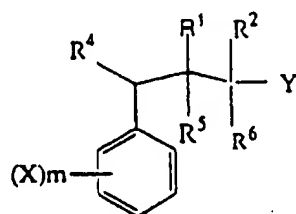
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activity, significant analgesic activity, no PCP-like stereotypic behavior in rodents (hyperexcitability and head weaving) at effective neuroprotectant, anticonvulsant and analgesic doses, no generalization to PCP in a PCP discrimination assay at effective neuroprotectant, anticonvulsant and analgesic doses, no neuronal vacuolization at effective neuroprotectant, anticonvulsant and analgesic doses, significantly less potent activity against voltage-sensitive calcium channels, and minimal hypotensive activity at effective neuroprotectant, anticonvulsant and analgesic doses. Such compounds may, however, inhibit the induction of LTP in rat hippocampal slices and may produce motor impairment at neuroprotectant, anticonvulsant and analgesic doses.

One aspect of the invention features a method for treating a patient having a neurological disease or disorder, comprising administering a compound of Formula I:



FORMULA I

wherein:

R<sup>1</sup> and R<sup>5</sup> are independently selected from the group consisting of phenyl, benzyl, and phenoxy (each of which is optionally substituted with alkyl, hydroxyalkyl, -OH, -O-alkyl, -O-acyl, -F, -Cl, -Br, -I, -CF<sub>3</sub>, or -OCF<sub>3</sub>), -H, alkyl, hydroxyalkyl, -OH, -O-alkyl, and O-acyl;

R<sup>2</sup> and R<sup>6</sup> are independently selected from the group

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consisting of -H, alkyl, and hydroxyalkyl; or R<sup>2</sup> and R<sup>6</sup> together are imino; or R<sup>1</sup> and R<sup>2</sup> together are -(CH<sub>2</sub>)<sub>n</sub>- or -(CH<sub>2</sub>)<sub>n</sub>-N(R<sup>3</sup>)-(CH<sub>2</sub>)<sub>n</sub>-;

R<sup>3</sup> is independently selected from the group  
5 consisting of -H, alkyl, 2-hydroxyethyl and alkylphenyl;  
n is an integer from 0 to 6, but at least one n must be greater than 0;

R<sup>4</sup> is selected from the group consisting of thiofuran, pyridyl, phenyl, benzyl, phenoxy, and  
10 phenylthio (each of which is optionally substituted with alkyl, -F, -Cl, -Br, -I, -CF<sub>3</sub>, -OH, -OCF<sub>3</sub>, -O-alkyl, or -O-acyl), -H, alkyl and cycloalkyl;

X is independently selected from the group consisting of phenyl, benzyl, and phenoxy (each of which  
15 is optionally substituted with -F, -Cl, -Br, -I, -CF<sub>3</sub>, alkyl, -OH, -OCF<sub>3</sub>, -O-alkyl, or -O-acyl) -F, -Cl, -Br, -I, CF<sub>3</sub>, alkyl, -OH, -OCF<sub>3</sub>, -O-alkyl, and O-acyl;

m is independently an integer from 0 to 5;

Y is -NR<sup>3</sup>R<sup>3</sup>, except when R<sup>1</sup> and R<sup>2</sup> together are  
20 -(CH<sub>2</sub>)<sub>n</sub>-N(R<sup>3</sup>)-(CH<sub>2</sub>)<sub>n</sub>-, then Y is -H;

and pharmaceutically acceptable salts and complexes thereof, wherein the compound is active at an NMDA receptor.

By "patient" is meant any animal that has a  
25 cell with an NMDA receptor. Preferably, the animal is a mammal. Most preferably, the animal is a human.

By "alkyl" is meant a branched or unbranched hydrocarbon chain containing between 1 and 6, preferably between 1 and 4, carbon atoms, such as, e.g., methyl,  
30 ethyl, n-propyl, iso-propyl, n-butyl, sec-butyl, iso-butyl, tert-butyl, 2-methylpentyl,

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cyclopropylmethyl, allyl, and cyclobutylmethyl.

By "lower alkyl" is meant a branched or unbranched hydrocarbon chain containing between 1 and 4 carbon atoms, of which examples are listed herein.

5 By "hydroxyalkyl" is meant an alkyl group as defined above, substituted with a hydroxyl group.

By "alkylphenyl" is meant an alkyl group as defined above, substituted with a phenyl group.

By "acyl" is meant -C(O)R, where R is H or  
10 alkyl as defined above, such as, e.g., formyl, acetyl, propionyl, or butyryl; or,

R is -O-alkyl such as in alkyl carbonates or R is N-alkyl such as in alkyl carbamates.

By "cycloalkyl" is meant a branched or  
15 unbranched cyclic hydrocarbon chain containing between 3 and 12 carbon atoms.

In preferred aspects of the invention,

Y is selected from the group consisting of -NH<sub>2</sub> and -NH-methyl;

20 R<sup>4</sup> is thiofuran, pyridyl, phenyl, benzyl, phenoxy, or phenylthio, each of which is optionally substituted with -F, -Cl, -Br, -I, -CF<sub>3</sub>, alkyl, -OH, -OCF<sub>3</sub>, -O-alkyl, or -O-acyl;

X is independently selected from the group  
25 consisting of meta-fluoro, meta-chloro, ortho-O-lower alkyl, ortho-methyl, ortho-fluoro, ortho-chloro, meta-O-lower alkyl, meta-methyl, ortho-OH, and meta-OH; and either

R<sup>1</sup>, R<sup>2</sup>, R<sup>5</sup>, and R<sup>6</sup> are -H;  
30 or R<sup>2</sup> is methyl, and R<sup>1</sup>, R<sup>5</sup>, and R<sup>6</sup> are -H;  
or R<sup>1</sup> is methyl, and R<sup>2</sup>, R<sup>5</sup>, and R<sup>6</sup> are -H.

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In other preferred aspects of the present invention,

$R^1$  and  $R^5$  are independently selected from the group consisting of -H, lower alkyl, hydroxyalkyl, -OH,  
5 -O-alkyl, and -O-acyl;

$R^2$  and  $R^6$  are independently selected from the group consisting of -H, lower alkyl, and hydroxyalkyl;

or  $R^1$  and  $R^2$  together are  $-(CH_2)_n-$  or  $-(CH_2)_n-N(R^3)-$ , and Y is H;

10  $R^3$  is independently selected from the group consisting of -H and lower alkyl;

$R^4$  is selected from the group consisting of thiofuran, pyridyl, phenyl, benzyl, phenoxy, and phenylthio (each of which is optionally substituted with  
15 lower alkyl, -F, -Cl, -Br, -I,  $-CF_3$ , -OH,  $-OCF_3$ , -O-alkyl, or -O-acyl), -H, lower alkyl, and cycloalkyl;

X is independently selected from the group consisting of -F, -Cl, -Br, -I,  $-CF_3$ , lower alkyl, -OH, and  $-OCF_3$ ;

20 m is independently an integer from 0 to 5;

Y is  $-NHR^3$ , or hydrogen when  $R^1$  and  $R^2$  together are  $-(CH_2)_n-N(R^3)-$ , and pharmaceutically acceptable salts and complexes thereof, with the provisos that

(a) when  $R^1$  and  $R^2$  together are  $-(CH_2)_n-N(R^3)-$ , then  
25  $R^5$ ,  $R^6$ , and Y are hydrogens; and

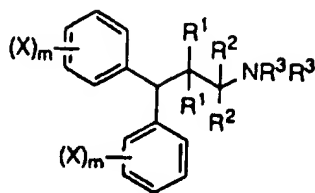
(b) when  $R^1$  and  $R^2$  together are not  $-(CH_2)_n-N(R^3)-$ , then Y is  $-NHR^3$ .

In one preferred aspect, the invention features a method for treating a patient having a  
30 neurological disease or disorder comprising administering a compound of Formula II:

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Formula II

wherein:

X is independently selected from the group  
 5 consisting of -H, -Br, -Cl, -F, -I, -CF<sub>3</sub>, alkyl, -OH,  
 -OCF<sub>3</sub>, -O-alkyl, and -O-acyl;

R<sup>1</sup> is independently selected from the group  
 consisting of -H, alkyl, hydroxyalkyl, -OH, -O-alkyl,  
 and -O-acyl;

10 R<sup>2</sup> is independently selected from the group  
 consisting of -H, alkyl, and hydroxyalkyl, or both R<sup>2</sup>'s  
 together are imino; R<sup>3</sup> is independently selected from the  
 group consisting of -H, alkyl, 2-hydroxyethyl, and  
 alkylphenyl; and m is independently an integer from 0 to  
 15 5.

Thus, in this preferred aspect, the compounds  
 include the compound of Formula I, wherein:

X is independently selected from the group  
 consisting of -F, -Cl, -Br, -I, -CF<sub>3</sub>, alkyl, -OH, -OCF<sub>3</sub>,  
 20 -O-alkyl, and -O-acyl;

R<sup>1</sup> is selected from the group consisting of -H,  
 alkyl, hydroxyalkyl, -OH, -O-alkyl, and -O-acyl;

R<sup>2</sup> and R<sup>6</sup> are independently selected from the group  
 consisting of -H, alkyl, and hydroxyalkyl, or R<sup>2</sup> and R<sup>6</sup>  
 25 together are imino;

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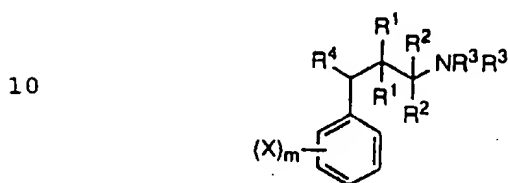
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$R^5$  is selected from the group consisting of -H, alkyl, hydroxyalkyl, -OH, -O-alkyl, and -O-acyl;

Y is  $NR^3R^3$ ; and

$R^4$  is phenyl, optionally substituted with alkyl, -F, -Cl, -Br, -I, -CF<sub>3</sub>, -OH, -OCF<sub>3</sub>, -O-alkyl, or -O-acyl.

In another preferred aspect, the administered compound has the structure of Formula III:



Formula III

wherein:

X is independently selected from the group consisting of -H, -Br, -Cl, -F, -I, -CF<sub>3</sub>, alkyl, -OH, -OCF<sub>3</sub>, -O-alkyl, and -O-acyl.

15  $R^1$  is independently selected from the group consisting of -H, alkyl, hydroxyalkyl, -OH, -O-alkyl, and -O-acyl;

$R^2$  is independently selected from the group consisting of -H, alkyl, and hydroxyalkyl, or both  $R^2$ s together are imino;

20  $R^3$  is independently selected from the group consisting of -H, alkyl, 2-hydroxyethyl, and alkylphenyl;

25  $R^4$  is selected from the group consisting of thiofuran, pyridyl, phenyl, benzyl, phenoxy, and phenylthio, (each of which is optionally substituted

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with (X)<sub>m</sub>), alkyl, and cycloalkyl; and, m is independently an integer from 0 to 5.

Thus, in the preferred aspect, the compounds include the compound of Formula I, wherein:

5 X is independently selected from the group consisting of -F, -Cl, -Br, -I, -CF<sub>3</sub>, alkyl, -OH, -OCF<sub>3</sub>, -O-alkyl, and -O-acyl;

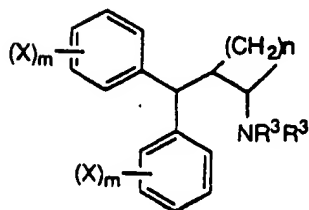
R<sup>1</sup> is selected from the group consisting of -H, alkyl, hydroxyalkyl, -OH, -O-alkyl, and -O-acyl;

10 R<sup>2</sup> and R<sup>6</sup> are selected from the group consisting of -H, alkyl, and hydroxyalkyl, or R<sup>2</sup> and R<sup>6</sup> together are imino;

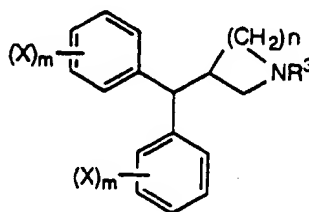
R<sup>5</sup> is independently selected from the group consisting of -H, alkyl, hydroxyalkyl, -OH, -O-alkyl, and -O-acyl; and

15 Y is NR<sup>3</sup>R<sup>3</sup>.

In another preferred aspect, the administered compound has the structure of Formulas IV and V.



Formula IV



Formula V

20

wherein:

n is an integer from 1 to 6;

X is independently selected from the group consisting of -H, -Br, -Cl, -F, -I -CF<sub>3</sub>, alkyl, -OH,



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-OCF<sub>3</sub>, -O-alkyl, and -O-acyl;

R<sup>3</sup> is independently selected from the group consisting of -H, alkyl, 2-hydroxyethyl, and alkylphenyl; and m is independently an integer from 0 to

5 5.

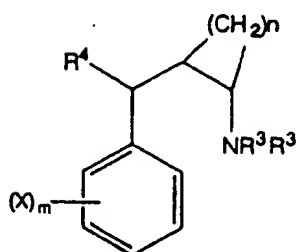
Thus, in this preferred aspect, the administered compounds include the compound of Formula I, wherein:

R<sup>3</sup> is independently selected from the group  
10 consisting of -H, and alkyl;

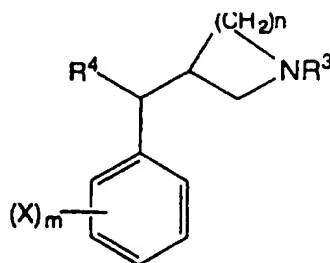
R<sup>4</sup> is phenyl, optionally substituted with alkyl, -F, -Cl, -Br, -I, -CF<sub>3</sub>, -OH, -OCF<sub>3</sub>, -O-alkyl, or -O-acyl; and

R<sup>1</sup> and R<sup>2</sup> together are -(CH<sub>2</sub>)<sub>n</sub>- or -(CH<sub>2</sub>)<sub>n</sub>-N(R<sup>3</sup>)-.

In another preferred aspect, the administered  
15 compound has the structure of Formulas VI and VII:



Formula VI



Formula VII

wherein:

n is an integer from 1 to 6;

X is independently selected from the group  
20 consisting of -H, -Br, -Cl, -F, -I, -CF<sub>3</sub>, alkyl, -OH, -OCF<sub>3</sub>, -O-alkyl, and -O-acyl;

R<sup>3</sup> is independently selected from the group

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consisting of -H, alkyl, 2-hydroxyethyl, and alkylphenyl;

R<sup>4</sup> is selected from the group consisting of thiofuran, pyridyl, phenyl, benzyl, phenoxy, and phenylthio (each of which is optionally substituted with (X)<sub>m</sub>), alkyl, and cycloalkyl; and m is independently an integer from 0 to 5.

Thus, in this preferred aspect, the administered compounds include the compound of Formula I, wherein:

X is independently selected from the group consisting of -F, -Cl, -Br, -I, CF<sub>3</sub>, alkyl, -OH, -OCF<sub>3</sub>, -O-alkyl, and -O-acyl-; and

R<sup>1</sup> and R<sup>2</sup> together are -(CH<sub>2</sub>)<sub>n</sub>- or -(CH<sub>2</sub>)<sub>n</sub>-N(R<sup>3</sup>)-.

More preferred aspects are those embodiments in which:

X is independently selected from the group consisting of meta-fluoro, meta-chloro, ortho-O-lower alkyl, ortho-methyl, ortho-fluoro, ortho-chloro, meta-O-lower alkyl, meta-methyl, ortho-OH, and meta-OH;

NR<sup>3</sup> is selected from the group consisting of NH, N-methyl, and N-ethyl;

NR<sup>3</sup>R<sup>3</sup> is selected from the group consisting of NH<sub>2</sub>, NH-methyl, and NH-ethyl;

R<sup>1</sup> is selected from the group consisting of -H and methyl;

R<sup>2</sup> is selected from the group consisting of -H and methyl; and

R<sup>4</sup> is selected from the group consisting of phenyl, benzyl, and phenoxy, each of which is optionally

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substituted with alkyl, -F, -Cl, -Br, -F, -CF<sub>3</sub>, -OH, -OCF<sub>3</sub>, -O-alkyl, or -O-acyl.

Especially preferred aspects are those embodiments in which:

5 X is meta-fluoro;

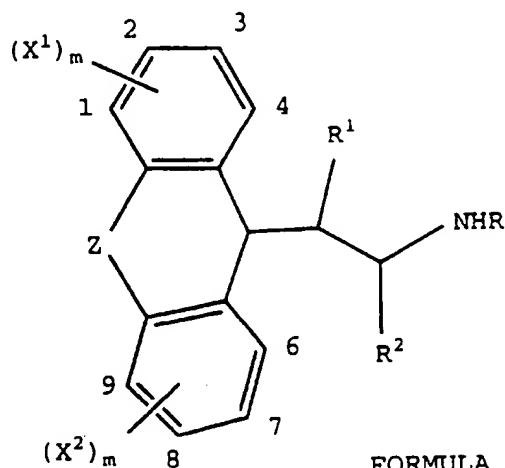
each R<sup>1</sup> and R<sup>2</sup> is -H;

NR<sup>3</sup> is selected from the group consisting of NH and N-methyl;

10 NR<sup>3</sup>R<sup>3</sup> is selected from the group consisting of NH<sub>2</sub> and NH-methyl; and

R<sup>4</sup> is selected from the group consisting of phenyl, benzyl, and phenoxy, each of which is optionally substituted with alkyl, -F, -Cl, -Br, -I, -CF<sub>3</sub>, -OH, -OCF<sub>3</sub>, -O-alkyl, or -O-acyl.

15 In a further aspect, the invention features a method for treating a patient having a neurological disease or disorder comprising administering the compounds of Formula VIII:



FORMULA VIII

20 wherein:

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Z is selected from the group consisting of  
-CH<sub>2</sub>CH<sub>2</sub>-, -CH<sub>2</sub>CH(CH<sub>3</sub>)-, -CH=CH-, -O-CH<sub>2</sub>-, -S-CH<sub>2</sub>-, -O-,  
and -S-;

5 X<sup>1</sup> and X<sup>2</sup> are independently selected from the group  
consisting of -F, -Cl, -CH<sub>3</sub>, -OH, and lower O-alkyl in  
the 1-, 3-, 7-, or 9-substituent positions;

m is independently an integer from 0 to 2;

-NHR is selected from the group consisting of  
-NH<sub>2</sub>, -NHCH<sub>3</sub>, and -NHC<sub>2</sub>H<sub>5</sub>;

10 R<sup>1</sup> is selected from the group consisting of -H,  
alkyl, hydroxyalkyl, -OH, -O-alkyl, and -O-acyl, and

R<sup>2</sup> is selected from the group consisting of -H,  
alkyl, hydroxyalkyl, and pharmaceutically acceptable  
salts and complexes thereof, wherein the compound is  
15 active at an NMDA receptor.

Especially preferred aspects are those  
embodiments in which:

Z is -CH<sub>2</sub>CH<sub>2</sub>-;

X<sup>1</sup> or X<sup>2</sup> is -F, or both X<sup>1</sup> and X<sup>2</sup> are -F;

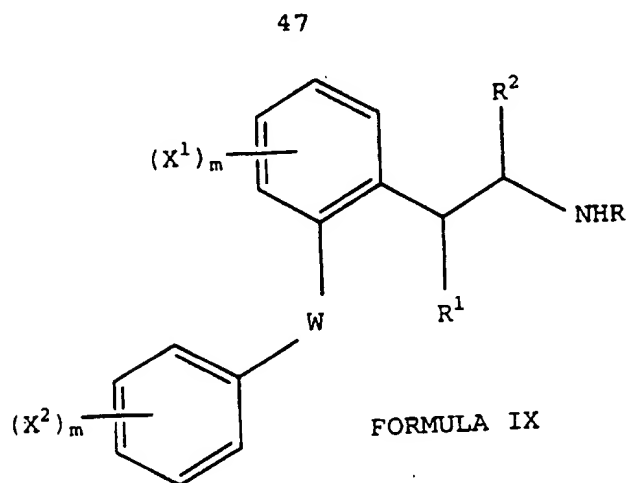
20 either R<sup>1</sup> or R<sup>2</sup> is methyl or both R<sup>1</sup> and R<sup>2</sup> are -H;  
and

-NHR is selected from the group consisting of  
-NH<sub>2</sub> or -NHCH<sub>3</sub>.

In other preferred embodiments, the invention  
25 features a method for treating a patient having a  
neurological disease or disorder comprising  
administering the compounds of Formula IX:

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wherein:

W is selected from the group consisting of  $-\text{CH}_2-$ ,  $-\text{O}-$ , and  $-\text{S}-$ ;

5  $\text{X}^1$  and  $\text{X}^2$  are independently selected from the group consisting of  $-\text{F}$ ,  $-\text{Cl}$ ,  $-\text{CH}_3$ ,  $-\text{OH}$ , and lower O-alkyl;

$m$  is independently an integer from 0 to 2;

$-\text{NHR}$  is selected from the group consisting of  $-\text{NH}_2$ ,  $-\text{NHCH}_3$ , and  $-\text{NHC}_2\text{H}_5$ ;

10  $\text{R}^1$  is selected from the group consisting of  $-\text{H}$ , alkyl, hydroxyalkyl,  $-\text{OH}$ ,  $-\text{O-alkyl}$ , and  $-\text{O-acyl}$ ; and

$\text{R}^2$  is selected from the group consisting of  $-\text{H}$ , alkyl, hydroxyalkyl, and pharmaceutically acceptable salts and complexes thereof, wherein the compound is  
15 active at an NMDA receptor.

In preferred aspects, the administered compound is selected from the group consisting of Compound 128, 129, 130, 131, 132, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214,  
20 and 215.

In preferred embodiments, the methods of treatment include administration of a compound selected from Compounds 19 through 215, or pharmaceutically acceptable salts and complexes thereof. Preferably, the

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compound has an  $IC_{50} \leq 10 \mu M$  at an NMDA receptor, more preferably  $\leq 2.5 \mu M$ , and most preferably  $\leq 0.5 \mu M$  at an NMDA receptor.

In further preferred embodiments, the methods of treatment include administration of a compound selected from the group consisting of Compound 19, 20, 21, 22, 23, 24, 25, 27, 28, 29, 30, 31, 32, 33, 34, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 75, 76, 77, 78, 79, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 100, 101, 102, 103, 105, 106, 107, 108, 109, 111, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138 (potential prodrug), 139, 141, 142, 143, 144, 145, 146, 147, 148, 149, and 150, and pharmaceutically acceptable salts and complexes thereof. These compounds have an  $IC_{50} \leq 10 \mu M$  at an NMDA receptor.

In more preferred embodiments, the methods of treatment include administration of a compound selected from the group consisting of Compound 19, 20, 21, 22, 23, 24, 25, 27, 28, 29, 30, 31, 32, 33, 34, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 69, 70, 75, 76, 81, 82, 83, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 100, 101, 102, 103, 105, 106, 108, 109, 111, 115, 118, 119, 120, 121, 122, 125, 126, 127, 128, 129, 130, 131, 132, 133, 135, 136, 137, 138 (potential prodrug), 139, 142, 144, 145, 146, 147, 148, 149, and 150, and pharmaceutically acceptable salts

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and complexes thereof. These compounds have an  $IC_{50} \leq 2.5 \mu M$  at an NMDA receptor

In other embodiments, the compound is selected from the group consisting of Compound 54, 55, 56, 57,  
5 58, 59, 60, 61, 62, 63, 64, 65, 66, 69, 76, 82, 83, 88,  
89, 90, 92, 93, 94, 95, 96, 101, 102, 103, 105, 109,  
111, 115, 118, 119, 120, 121, 122, 125, 126, 127, 129,  
130, 131, 135, 136, 137, 138, 139, 142, 144, 145, 148,  
149, and 150, and pharmaceutically acceptable salts and  
10 complexes thereof.

In particularly preferred embodiments, the methods of treatment include administration of a compound selected from the group consisting of Compound  
19, 20, 21, 22, 23, 24, 25, 27, 28, 30, 31, 32, 33, 38,  
15 39, 43, 44, 46, 47, 49, 50, 52, 53, 54, 55, 56, 57, 58,  
59, 60, 61, 62, 63, 64, 65, 66, 69, 82, 83, 89, 90, 91,  
93, 94, 95, 96, 97, 103, 111, 118, 119, 120, 122, 126,  
135, 136, 137, 138 (potential prodrug), 142, 144, 145,  
147, 148, 149, and 150, and pharmaceutically acceptable  
20 salts and complexes thereof. These compounds have an  
 $IC_{50} \leq 0.5 \mu M$  at an NMDA receptor.

In more preferred embodiments, the methods of treatment include administration of a compound selected from the group consisting of Compound 20, 24, 25, 33,  
25 50, 60, 66, 69, 103, 111, 118, 119, 120, 122, 136, 137,  
138 (potential prodrug), 142, 144, 145, 148, 149, and  
150, and pharmaceutically acceptable salts and complexes  
thereof.

In particularly preferred embodiments, the  
30 methods of treatment include administration of a  
compound selected from the group consisting of Compound

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20, 33, 50, 60, 119, and 144, and pharmaceutically acceptable salts and complexes thereof.

In other particularly preferred embodiments, the methods of treatment include administration of a compound selected from the group consisting of Compound 33, 50, 60, 119, and 144, and pharmaceutically acceptable salts and complexes thereof.

In preferred aspects, the invention provides a method for treating a patient having a neurological disease or disorder, comprising administering a compound which is selected from the group consisting of Compound 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 181, 182, 183, 184, 185, 186, 187, and pharmaceutically acceptable salts and complexes thereof. These compounds have an  $IC_{50} \leq 10\mu M$  at an NMDA receptor.

In further preferred aspects, the invention provides a method for treating a patient having a neurological disease or disorder, comprising administering a compound which is selected from the group consisting of Compound 157, 158, 159, 163, 164, 166, 167, 168, 169, 170, 171, 181, 185, 186, and pharmaceutically acceptable salts and complexes thereof. These compounds have an  $IC_{50} \leq 10\mu M$  at an NMDA receptor.

In other more preferred aspects, the invention provides a method for treating a patient having a neurological disease or disorder, comprising administering a compound which is selected from the group consisting of Compound 156, 157, 158, 159, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 181, 183, 184, 185, 186, 187, and pharmaceutically acceptable



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salts and complexes thereof. These compounds have an  $IC_{50} \leq 2.5 \mu M$  at an NMDA receptor.

In further preferred aspects, the invention provides a method for treating a patient having a neurological disease or disorder, comprising administering a compound which is selected from the group consisting of Compound 157, 158, 159, 163, 164, 166, 167, 168, 169, 170, 171, 181, 185, 186, and pharmaceutically acceptable salts and complexes thereof. These compounds have an  $IC_{50} \leq 2.5 \mu M$  at an NMDA receptor.

In other particularly preferred aspects, the invention provides a method for treating a patient having a neurological disease or disorder, comprising administering a compound which is selected from the group consisting of Compound 156, 157, 158, 159, 161, 163, 164, 165, 167, 168, 169, 170, 171, 181, 186 and pharmaceutically acceptable salts and complexes thereof. These compounds have an  $IC_{50} \leq 0.5 \mu M$  at an NMDA receptor.

In further preferred aspects, the invention provides a method for treating a patient having a neurological disease or disorder, comprising administering a compound which is selected from the group consisting of Compound 157, 158, 159, 163, 164, 167, 168, 169, 170, 171, 181, 186 and pharmaceutically acceptable salts and complexes thereof. These compounds have an  $IC_{50} \leq 0.5 \mu M$  at an NMDA receptor.

In other preferred aspects, the invention provides a method for treating a patient having a neurological disease or disorder comprising

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administering a compound selected from the group consisting of Compounds 151 - 215, and pharmaceutically acceptable salts and complexes thereof.

In more preferred aspects, the invention provides a method for treating a patient having a neurological disease or disorder comprising administering a compound selected from the group consisting of Compound 151, 152, 153, 154, 155, 157, 158, 159, 163, 164, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 181, 185, 186, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215 and pharmaceutically acceptable salts and complexes thereof.

The present invention provides simplified arylalkylamines comprising the compounds of Formulas I-IX and all preferred aspects of Formulas I-IX as set out above.

Examples of such simplified arylalkylamines include, but are not limited to, Compounds 19 - 215, whose structures are provided below. Preferably, the compound has an  $IC_{50} \leq 10 \mu M$  at an NMDA receptor. More preferably, the compound has an  $IC_{50} \leq 5 \mu M$ , more preferably  $\leq 2.5 \mu M$ , and most preferably  $\leq 0.5 \mu M$  at an NMDA receptor.

In preferred embodiments, the compound is selected from the group consisting of Compound 21, 22, 23, 24, 25, 26, 27, 28, 29, 33, 34, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 69, 76, 78, 79, 82, 83, 84, 88, 89, 90, 92, 93, 94, 95, 96, 98, 101,

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102, 103, 105, 107, 108, 109, 111, 115, 116, 118, 119,  
120, 121, 122, 124, 125, 126, 127, 129, 130, 131, 134,  
135, 136, 137, 138 (potential prodrug), 139, 141, 142,  
143, 144, 145, 148, 149, and 150. These compounds have  
5 an  $IC_{50} \leq 10 \mu M$  at an NMDA receptor.

In other embodiments, the compound is selected  
from the group consisting of Compound 54, 55, 56, 57,  
58, 59, 60, 61, 62, 63, 64, 65, 66, 69, 76, 82, 83, 88,  
89, 90, 92, 93, 94, 95, 96, 101, 102, 103, 105, 109,  
10 111, 115, 118, 119, 120, 121, 122, 125, 126, 127, 129,  
130, 131, 135, 136, 137, 138, 139, 142, 144, 145, 148,  
149, and 150.

In more preferred embodiments, the compound is  
selected from the group consisting of Compound 21, 22,  
15 23, 24, 25, 27, 28, 29, 33, 34, 37, 38, 39, 40, 41, 42,  
43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56,  
57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 69, 76, 82, 83,  
88, 89, 90, 92, 93, 94, 95, 96, 101, 102, 103, 105, 108,  
109, 111, 115, 118, 119, 120, 121, 122, 125, 126, 127,  
20 129, 130, 131, 135, 136, 137, 138 (potential prodrug),  
139, 142, 144, 145, 148, 149, and 150. These compounds  
have an  $IC_{50} \leq 2.5 \mu M$  at an NMDA receptor.

In particularly preferred embodiments, the  
compound is selected from the group consisting of  
25 Compound 21, 22, 23, 24, 25, 27, 28, 33, 38, 39, 43, 44,  
46, 47, 49, 50, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61,  
62, 63, 64, 65, 66, 69, 82, 83, 89, 90, 93, 94, 95, 96,  
103, 111, 118, 119, 120, 122, 126, 135, 136, 137, 138  
(potential prodrug), 142, 144, 145, 148, 149, and 150.  
30 These compounds have an  $IC_{50} \leq 0.5 \mu M$  at an NMDA  
receptor.

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In preferred embodiments, the compound is selected from the group consisting of Compound 24, 25, 33, 50, 60, 66, 69, 103, 111, 118, 119, 120, 122, 136, 137, 138, 142, 144, 145, 148, 149, and 150.

5 In particularly preferred embodiments, the compound is selected from the group consisting of Compound 20, 33, 50, 60, 119, and 144.

In more particularly preferred embodiments, the compound is selected from the group consisting of  
10 Compound 33, 50, 60, 119, and 144.

In other preferred aspects, the compound is selected from the group consisting of Compound 151, 152, 153, 154, 155, 157, 158, 159, 163, 164, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 181, 185, 186,  
15 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215 and pharmaceutically acceptable salts and complexes thereof.

In other preferred aspects, the compound is  
20 selected from the group consisting of Compound 157, 158, 159, 163, 164, 166, 167, 168, 169, 170, 171, 181, 185, 186, and pharmaceutically acceptable salts and complexes thereof. These compounds have an  $IC_{50} \leq 10 \mu M$  at an NMDA receptor.

25 In more preferred aspects, the compound is selected from the group consisting of Compound 157, 158, 159, 163, 164, 167, 168, 169, 170, 171, 181, 185, 186, and pharmaceutically acceptable salts and complexes thereof. These compounds have an  $IC_{50} \leq 2.5 \mu M$  at an  
30 NMDA receptor.

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In most preferred aspects, the compound is selected from the group consisting of Compound 157, 158, 159, 163, 164, 167, 168, 169, 170, 171, 181, 186, and pharmaceutically acceptable salts and complexes thereof.

5 These compounds have an  $IC_{50} \leq 0.5 \mu M$  at an NMDA receptor.

Excluded from the composition of matter aspect of the present invention are known compounds whose chemical structures are covered by the generic

10 formulae presented above.

Also provided in an aspect of the invention are pharmaceutical compositions useful for treating a patient having a neurological disease or disorder. The pharmaceutical compositions are provided in a

15 pharmaceutically acceptable carrier and appropriate dose. The pharmaceutical compositions may be in the form of pharmaceutically acceptable salts and complexes, as is known to those skilled in the art.

The pharmaceutical compositions comprise the

20 compounds of Formulas I-IX and all preferred aspects of Formulas I-IX as set out above.

Preferred pharmaceutical compositions comprise Compounds 19 - 215. Preferably, the compound has an  $IC_{50} \leq 10 \mu M$  at an NMDA receptor. More preferably the

25 compound has an  $IC_{50} \leq 5 \mu M$ , more preferably  $\leq 2.5 \mu M$ , and most preferably  $\leq 0.5 \mu M$  at an NMDA receptor.

In further preferred embodiments, the pharmaceutical composition comprises a compound selected from the group consisting of Compound 20, 21, 22, 23,

30 24, 25, 27, 28, 29, 30, 31, 32, 33, 34, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54,

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55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68,  
69, 70, 71, 72, 73, 75, 76, 77, 78, 79, 81, 82, 83, 84,  
85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98,  
100, 101, 102, 103, 105, 106, 107, 108, 109, 111, 114,  
5 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125,  
126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136,  
137, 138 (potential prodrug), 139, 141, 142, 143, 144,  
145, 146, 147, 148, 149, and 150. These compounds have  
an  $IC_{50} \leq 10\mu M$  at an NMDA receptor.

10 Preferably, the compound is selected from the  
group consisting of 21, 22, 23, 24, 25, 26, 27, 28, 29,  
33, 34, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48,  
49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62,  
63, 64, 65, 66, 69, 76, 78, 79, 82, 83, 84, 88, 89, 90,  
15 92, 93, 94, 95, 96, 98, 101, 102, 103, 105, 107, 108,  
109, 111, 115, 116, 118, 119, 120, 121, 122, 124, 125,  
126, 127, 129, 130, 131, 134, 135, 136, 137, 138  
(potential prodrug), 139, 141, 142, 143, 144, 145, 148,  
149, and 150.

20 In other embodiments, the compound is selected  
from the group consisting of 54, 55, 56, 57, 58, 59, 60,  
61, 62, 63, 64, 65, 66, 69, 76, 82, 83, 88, 89, 90, 92,  
93, 94, 95, 96, 101, 102, 103, 105, 109, 111, 115, 118,  
119, 120, 121, 122, 125, 126, 127, 129, 130, 131, 135,  
25 136, 137, 138, 139, 142, 144, 145, 148, 149, and 150.

In more preferred embodiments, the  
pharmaceutical composition comprises a compound selected  
from the group consisting of Compound 20, 21, 22, 23,  
24, 25, 27, 28, 29, 30, 31, 32, 33, 34, 37, 38, 39, 40,  
30 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54,  
55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 69, 70,

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75, 76, 81, 82, 83, 85, 86, 87, 88, 89, 90, 91, 92, 93,  
94, 95, 96, 97, 100, 101, 102, 103, 105, 106, 108, 109,  
111, 115, 118, 119, 120, 121, 122, 125, 126, 127, 128,  
129, 130, 131, 132, 133, 135, 136, 137, 138 (potential  
5 prodrug), 139, 142, 144, 145, 146, 148, 149, and 150.

These compounds have an  $IC_{50} \leq 2.5 \mu M$  at an NMDA  
receptor.

Preferably, the compound is selected from the  
group consisting of 21, 22, 23, 24, 25, 27, 28, 29, 33,  
10 34, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49,  
50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63,  
64, 65, 66, 69, 76, 82, 83, 88, 89, 90, 92, 93, 94, 95,  
96, 101, 102, 103, 105, 108, 109, 111, 115, 118, 119,  
120, 121, 122, 125, 126, 127, 129, 130, 131, 135, 136,  
15 137, 138 (potential prodrug), 139, 142, 144, 145, 148,  
149, and 150.

In particularly preferred embodiments, the  
pharmaceutical composition comprises a compound is  
selected from the group consisting of Compound 20, 21,  
20 22, 23, 24, 25, 27, 28, 30, 31, 32, 33, 38, 39, 43, 44,  
46, 47, 49, 50, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61,  
62, 63, 64, 65, 66, 69, 82, 83, 89, 90, 91, 93, 94, 95,  
96, 97, 103, 111, 118, 119, 120, 122, 126, 135, 136,  
137, 138 (potential prodrug), 142, 144, 145, 148, 149,  
25 and 150. These compounds have an  $IC_{50} \leq 0.5 \mu M$  at an  
NMDA receptor.

Preferably, the compound is selected from the  
group consisting of 21, 22, 23, 24, 25, 27, 28, 33, 38,  
39, 43, 44, 46, 47, 49, 50, 52, 53, 54, 55, 56, 57, 58,  
30 59, 60, 61, 62, 63, 64, 65, 66, 69, 82, 83, 89, 90, 93,  
94, 95, 96, 103, 111, 118, 119, 120, 122, 126, 135, 136,

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137, 138 (potential prodrug), 142, 144, 145, 148, 149, and 150.

In more preferred embodiments, the pharmaceutical composition comprises a compound selected from the group consisting of Compound 20, 24, 25, 33, 50, 60, 66, 69, 103, 111, 118, 119, 120, 122, 136, 137, 138, 142, 144, 145, 148, 149, and 150.

Preferably, the compound is selected from the group consisting of Compound 24, 25, 33, 50, 60, 66, 69, 103, 111, 118, 119, 120, 122, 136, 137, 138, 142, 144, 145, 148, 149, and 150.

In most particularly preferred embodiments, the pharmaceutical composition comprises a compound selected from the group consisting of Compound 20, 33, 50, 60, 119, and 144.

Preferably, the compound is selected from the group consisting of 33, 50, 60, 119, and 144.

In other preferred aspects, the pharmaceutical composition comprises a compound selected from the group consisting of compound 151, 152, 153, 154, 155, 157, 158, 159, 163, 164, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 181, 185, 186, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215 and pharmaceutically acceptable salts and complexes thereof, and a pharmaceutically acceptable carrier.

In other preferred aspects the pharmaceutical composition comprises a compound which is selected from the group consisting of Compound 157, 158, 159, 163, 164, 166, 167, 168, 169, 170, 171, 181, 185, 186, and



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pharmaceutically acceptable salts and complexes thereof, and a pharmaceutically acceptable carrier. These compounds have an  $IC_{50} \leq 10 \mu M$  at an NMDA receptor.

In more preferred aspects, the pharmaceutical composition comprises a compound which is selected from the group consisting of Compound 157, 158, 159, 163, 164, 166, 167, 168, 169, 170, 171, 181, 185, 186, and pharmaceutically acceptable salts and complexes thereof, and a pharmaceutically acceptable carrier. These compounds have an  $IC_{50} \leq 2.5 \mu M$  at an NMDA receptor.

In most preferred aspects, the pharmaceutical composition comprises a compound which is selected from the group consisting of Compound 157, 158, 159, 163, 164, 167, 168, 169, 170, 171, 181, 186, and pharmaceutically acceptable salts and complexes thereof, and a pharmaceutically acceptable carrier. These compounds have an  $IC_{50} \leq 0.5 \mu M$  at an NMDA receptor.

Structural modifications can be made to compounds such as 20 or 60 which do not add materially to the structure-activity relationships (SAR) illustrated here. For example, successful bioisosteric replacement or substitution of optionally substituted phenyl groups, such as those occurring in Compounds 20 or 60, can be accomplished with other lipophilic or semi-polar aromatic (e.g., naphthyl, naphthoxy, benzyl, phenoxy, phenylthio), aliphatic (alkyl, e.g., isopropyl), cycloaliphatic (cycloalkyl, e.g., cyclohexyl), heterocyclic [e.g., pyridyl, furanyl, thiofuranyl (thiophenyl)], or other functional groups or systems, as is well known in the art, will afford clinically useful compounds (structural homologs,

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analogs, and/or congeners) with similar biopharmaceutical properties and activity at the NMDA receptor (e.g., cf. Compounds 37, 75, 79, 83, 89, 119-122, 125, 126, 128, 130, 132, 137, 144, and 145). For example, such replacements or substitutions have been used to great effect in the development of SAR among other groups of highly clinically and commercially successful synthetic pharmaceutical agents such as the classical H<sub>1</sub>-antihistamines, anticholinergics (antimuscarinics; e.g., anti-Parkinsonians), antidepressants (including tricyclic compounds), and opioid analgesics [See, Foye et al. (Eds.), *Principles of Medicinal Chemistry*, 4th ed., Lea and Febiger/Williams and Wilkins, Philadelphia, PA, 1995, pp. 233, 265, 281-282, 340-341, 418-427, and 430; Prous, J.R., *The Year's Drug News, Therapeutic Targets - 1995 Edition*, Prous Science Publishers, Barcelona, Spain, 1995, pp. 13, 55-56, 58-59, 74, 89, 144-145, 152, 296-297, and 317]. Similarly, bioisosteric replacement or substitution of the methylene or methine groups in the propyl backbone of compounds such as 20 or 60 with, e.g., oxygen, sulfur, or nitrogen, will afford clinically useful NMDA receptor-active compounds with similarly useful biopharmaceutical properties, such as Compound 88 (a modified "classical H<sub>1</sub>-antihistamine-type" structure), which can be further optimized for activity at the NMDA receptor by preparing, e.g., the corresponding compound(s) containing, e.g., (bis)(3-fluorophenyl) group(s), as taught by the present invention. The propyl backbone of compounds such as 20 and 60 may also be modified successfully by the

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incorporation of ring systems (as in Compounds 102 and 111) and/or unsaturation (e.g., a double bond, as in Compounds 81, 106, 109, and 139) to afford further clinically useful NMDA receptor-active compounds of the present invention (cf. compounds cited above).

In a related aspect, the invention features a method for making a therapeutic agent comprising the steps of screening for said agent by determining whether said agent is active on a receptor-operated calcium channel, and synthesizing said therapeutic agent in an amount sufficient to provide said agent in a therapeutically effective amount to a patient. Said screening may be performed by methods known to those of ordinary skill in the art, and may, for example be performed by the methods set out herein. Those skilled in the art are also familiar with methods used to synthesize therapeutic agents in amounts sufficient to be provided in a therapeutically effective amount.

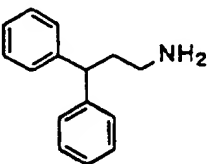
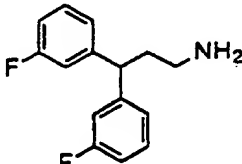
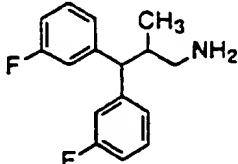
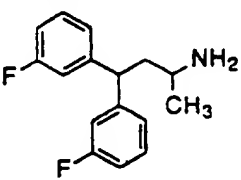
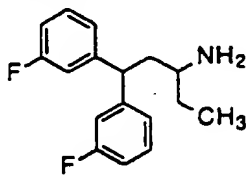
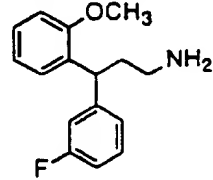
In a preferred aspect, said receptor-operated calcium channel is an NMDA receptor. In a more preferred aspect, said method further comprises the step of adding a pharmaceutically acceptable carrier to said agent. In a further preferred aspect said therapeutic agent comprises a compound of Formula I, as set out herein. In a further preferred aspect said therapeutic agent comprises a compound of Formula II, III, IV, V, VI, VII, VIII, or IX, as set out herein. In particularly preferred aspects, said therapeutic agent comprises a compound having a structure selected from the group consisting of Formulas I-IX, and all preferred aspects of said formulas as set out herein. In further

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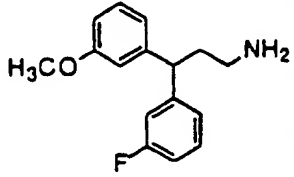
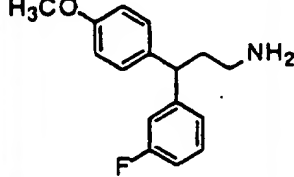
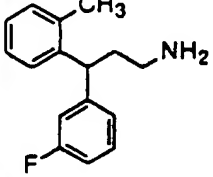
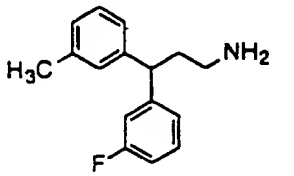
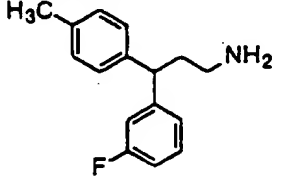
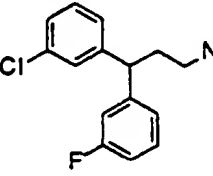
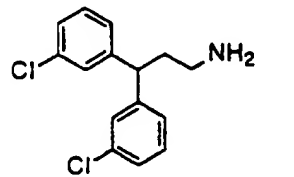
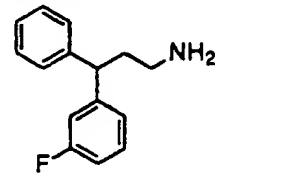
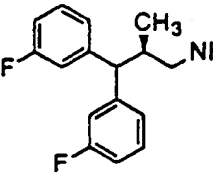
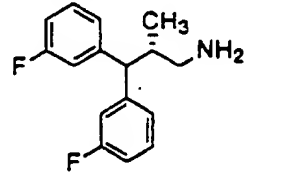
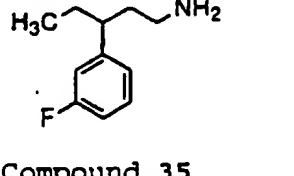
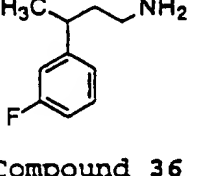
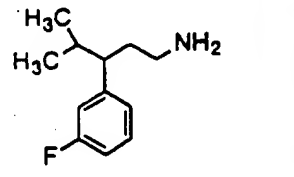
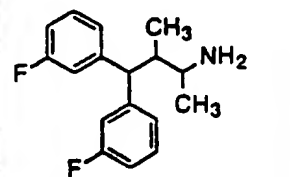
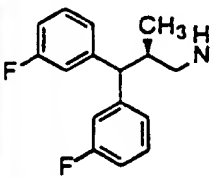
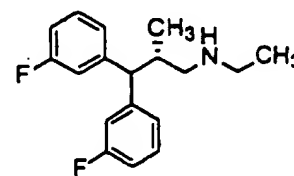
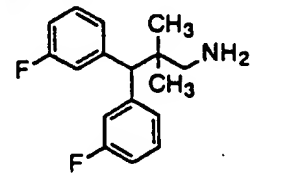
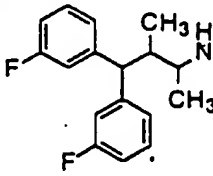
preferred aspects, said therapeutic agent is selected from the group consisting of Compounds 19-215. In a particularly preferred aspect, said therapeutic agent is provided to a patient having a neurological disease or disorder. In a related aspect, said screening comprises the step of identifying a compound which binds to said receptor-operated calcium channel at a site bound by one of the arylalkylamines Compound 1, Compound 2, and Compound 3.

|  |  |   |
|--|--|---|
| <br>Compound 19  | <br>Compound 20  | <br>Compound 21  |
| <br>Compound 22 | <br>Compound 23 | <br>Compound 24 |

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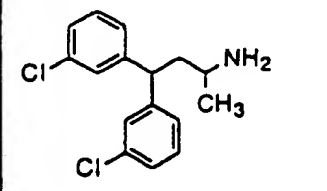
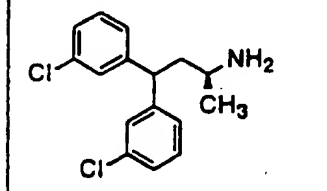
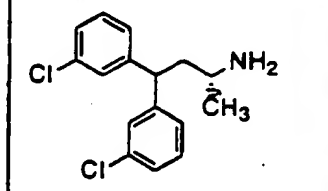
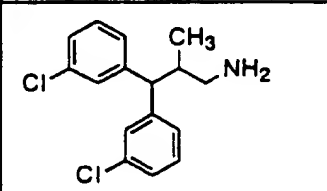
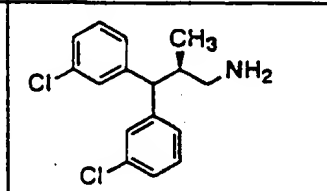
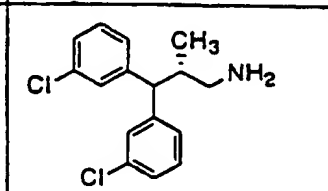
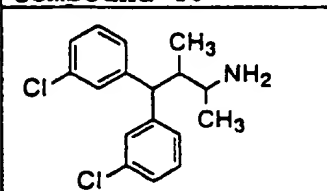
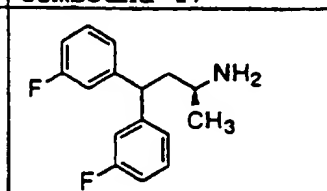
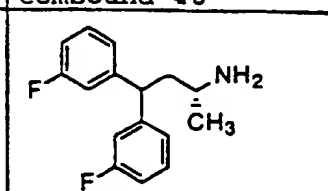
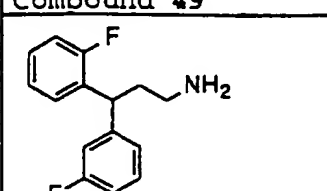
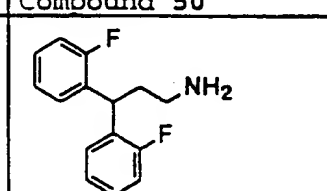
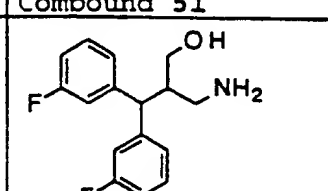
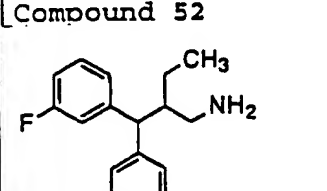
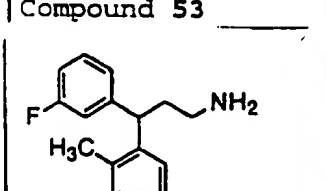
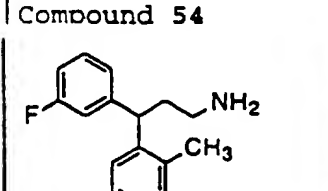
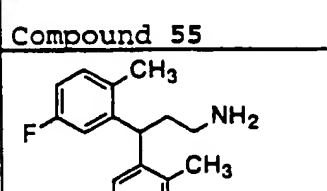
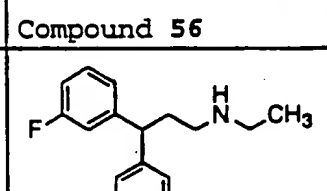
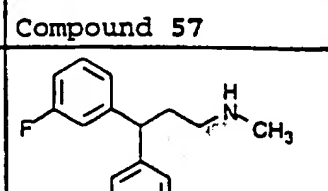
63

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|--|--|--|
| <br>Compound 25   | <br>Compound 26   | <br>Compound 27   |
| <br>Compound 28   | <br>Compound 29   | <br>Compound 30   |
| <br>Compound 31  | <br>Compound 32  | <br>Compound 33  |
| <br>Compound 34 | <br>Compound 35 | <br>Compound 36 |
| <br>Compound 37 | <br>Compound 38 | <br>Compound 39 |
| <br>Compound 40 | <br>Compound 41 | <br>Compound 42 |

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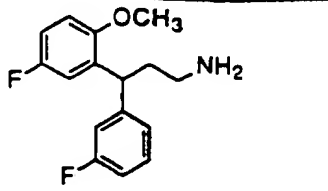
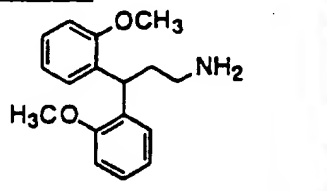
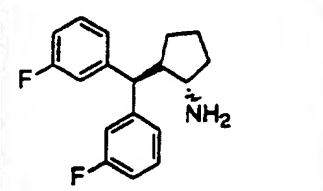
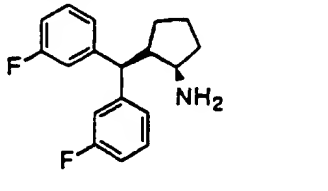
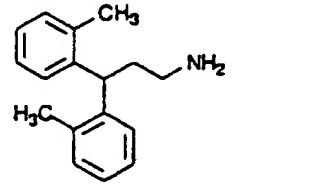
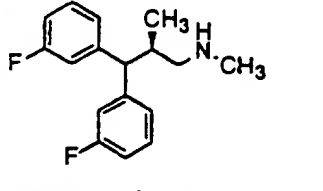
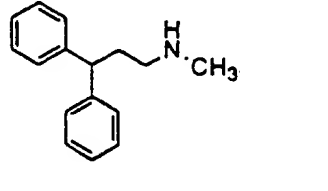
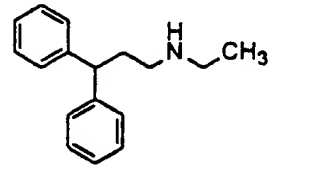
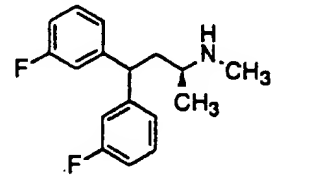
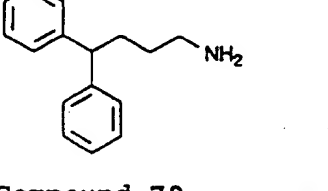
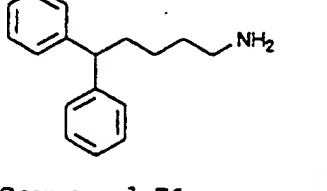
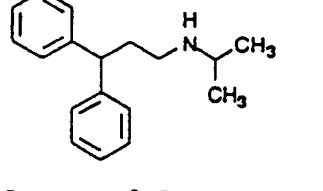
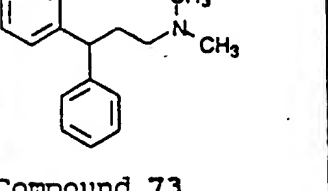
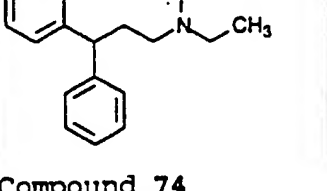
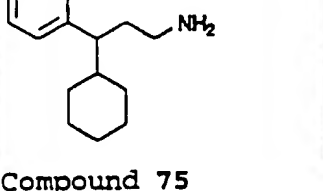
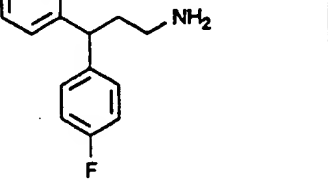
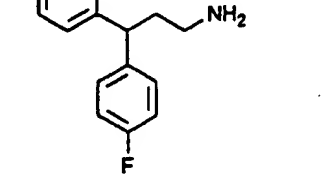
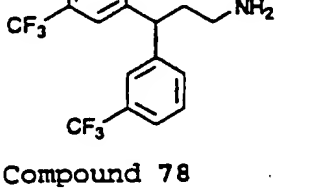
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|  |  |   |
|--|--|---|
| <br>Compound 43   | <br>Compound 44   | <br>Compound 45   |
| <br>Compound 46   | <br>Compound 47   | <br>Compound 48   |
| <br>Compound 49  | <br>Compound 50  | <br>Compound 51  |
| <br>Compound 52 | <br>Compound 53 | <br>Compound 54 |
| <br>Compound 55 | <br>Compound 56 | <br>Compound 57 |
| <br>Compound 58 | <br>Compound 59 | <br>Compound 60 |

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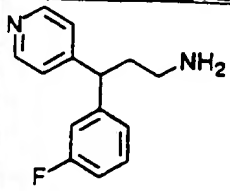
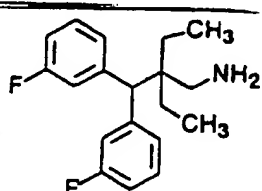
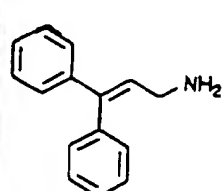
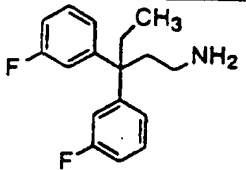
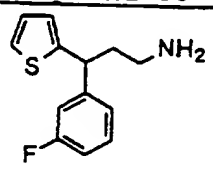
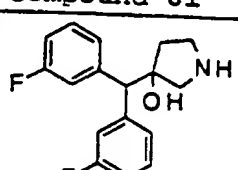
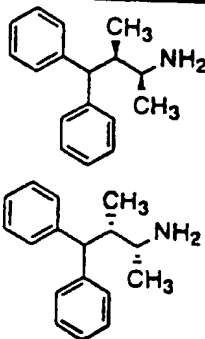
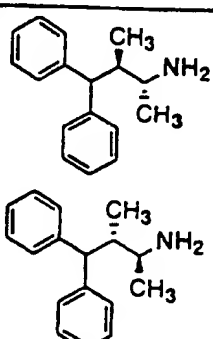
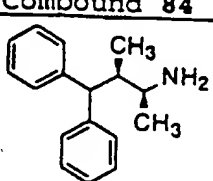
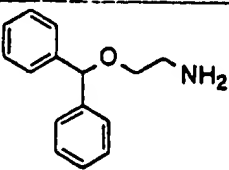
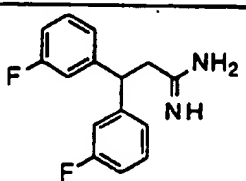
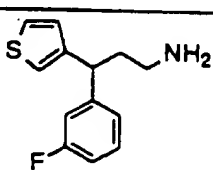
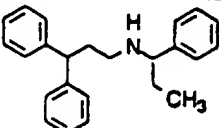
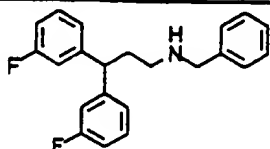
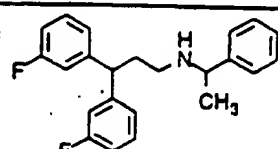
65

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|--|--|--|
| <br>Compound 61   | <br>Compound 62   | <br>Compound 63   |
| <br>Compound 64   | <br>Compound 65   | <br>Compound 66   |
| <br>Compound 67  | <br>Compound 68  | <br>Compound 69  |
| <br>Compound 70 | <br>Compound 71 | <br>Compound 72 |
| <br>Compound 73 | <br>Compound 74 | <br>Compound 75 |
| <br>Compound 76 | <br>Compound 77 | <br>Compound 78 |

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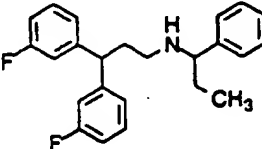
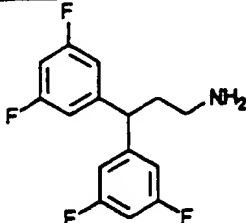
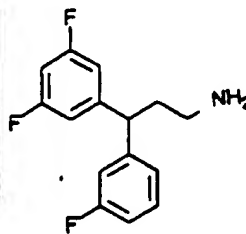
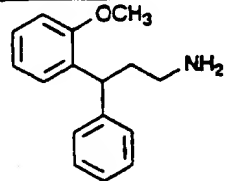
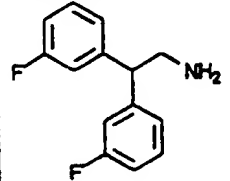
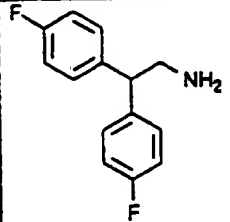
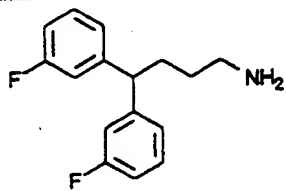
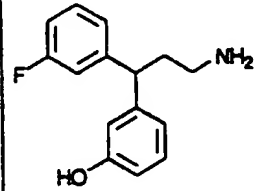
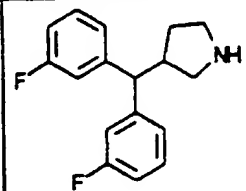
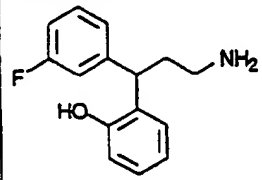
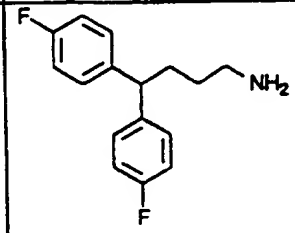
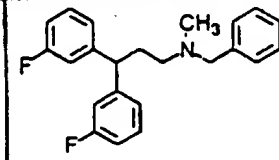
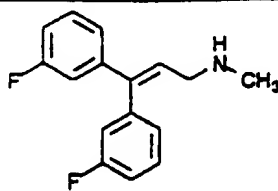
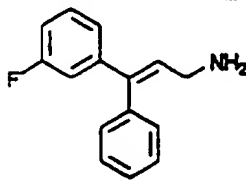
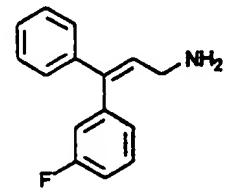
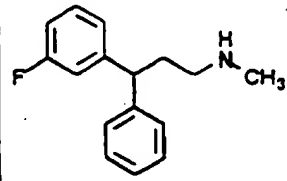
|  |  |   |
|--|--|---|
| <br>Compound 79                                 | <br>Compound 80                                 | <br>Compound 81  |
| <br>Compound 82                                 | <br>Compound 83                                 | <br>Compound 84   |
| <br>Compound 85<br>(mixture of 2<br>compounds) | <br>Compound 86<br>(mixture of 2<br>compounds) | <br>Compound 87  |
| <br>Compound 88                               | <br>Compound 89                               | <br>Compound 90 |
| <br>Compound 91                               | <br>Compound 92                               | <br>Compound 93 |



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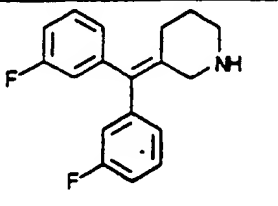
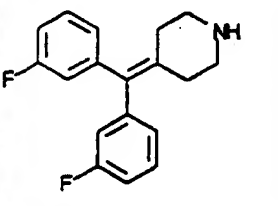
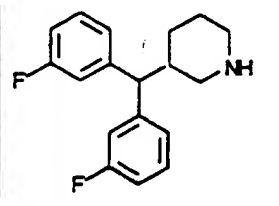
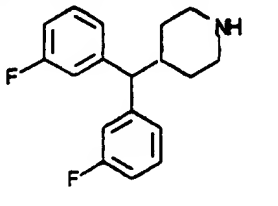
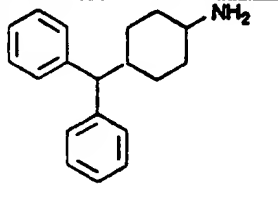
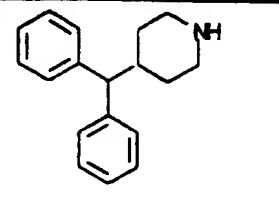
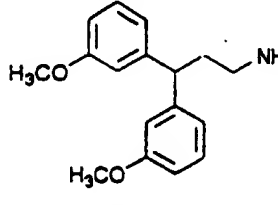
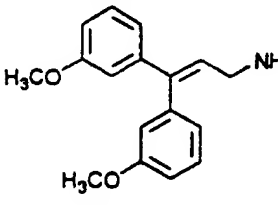
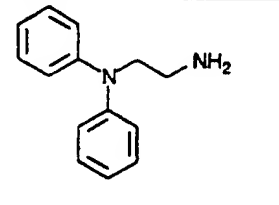
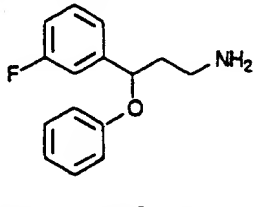
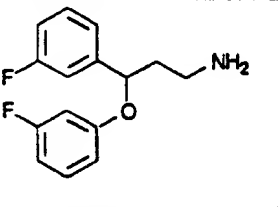
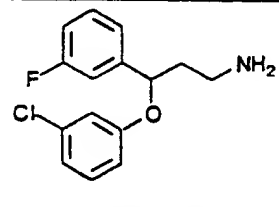
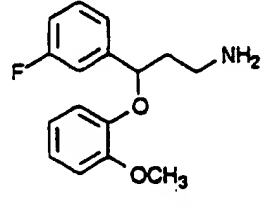
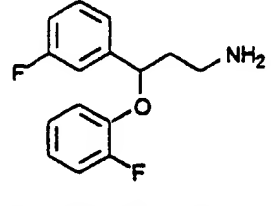
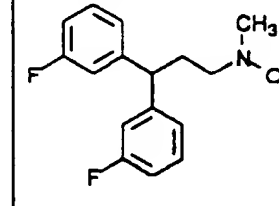
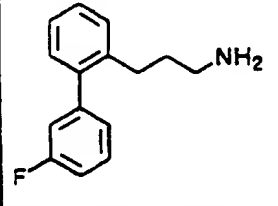
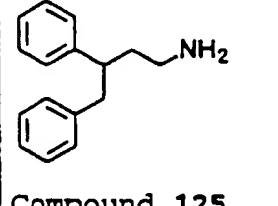
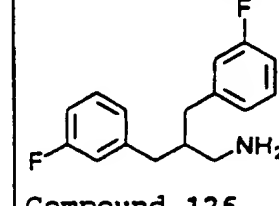
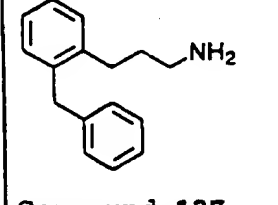
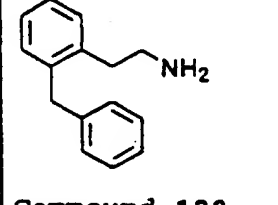
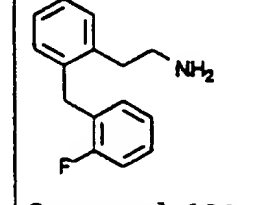
67

|   |   |  |
|---|---|--|
| <br>Compound 94    | <br>Compound 95  | <br>Compound 96    |
| <br>Compound 97    | <br>Compound 98  | <br>Compound 99    |
| <br>Compound 100  | <br>Compound 101  | <br>Compound 102  |
| <br>Compound 103 | <br>Compound 104   | <br>Compound 105 |
| <br>Compound 106 | <br><br>Compound 107<br>(mixture of 2<br>compounds) | <br>Compound 108 |

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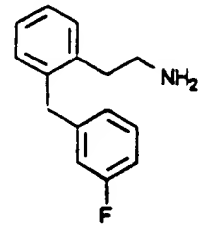
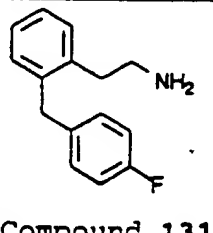
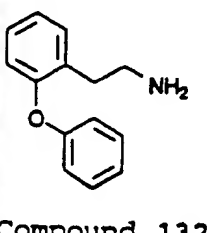
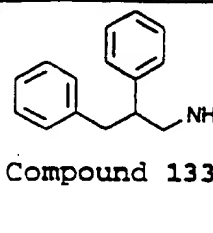
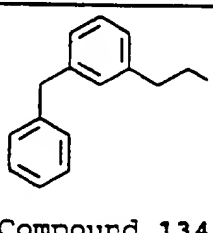
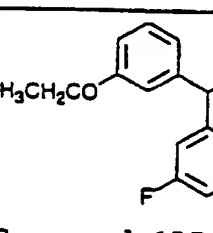
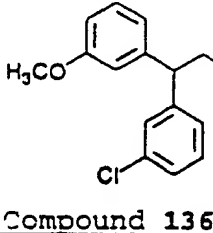
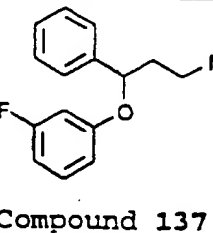
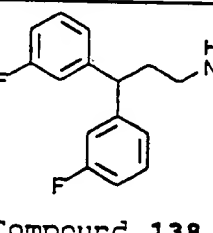
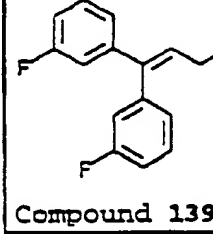
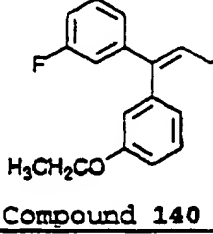
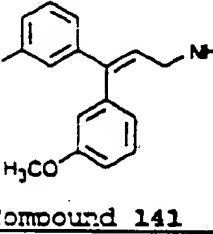
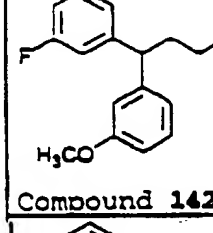
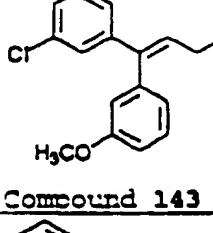
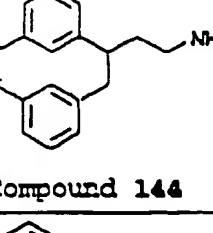
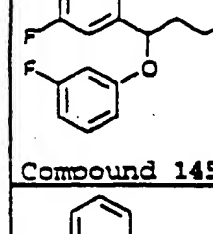
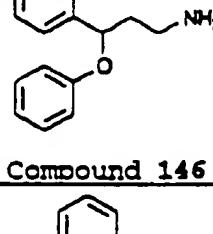
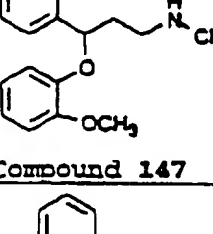
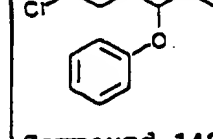
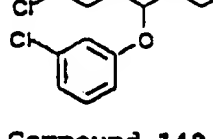
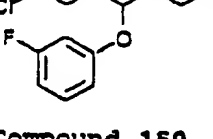
68

|   |   |  |
|---|---|--|
| <br>Compound 109   | <br>Compound 110   | <br>Compound 111   |
| <br>Compound 112   | <br>Compound 113   | <br>Compound 114   |
| <br>Compound 115   | <br>Compound 116   | <br>Compound 117   |
| <br>Compound 118 | <br>Compound 119 | <br>Compound 120 |
| <br>Compound 121 | <br>Compound 122 | <br>Compound 123 |
| <br>Compound 124 | <br>Compound 125 | <br>Compound 126 |
| <br>Compound 127 | <br>Compound 128 | <br>Compound 129 |

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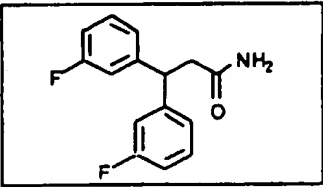
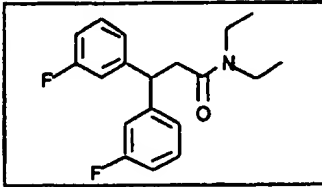
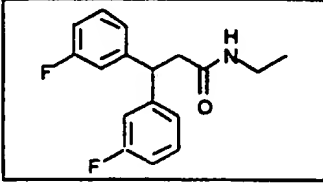
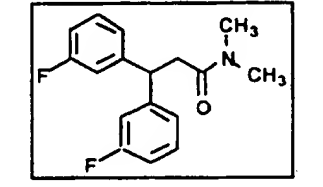
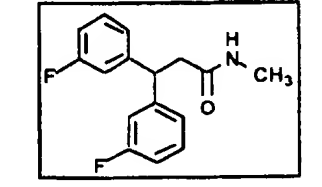
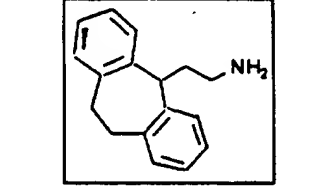
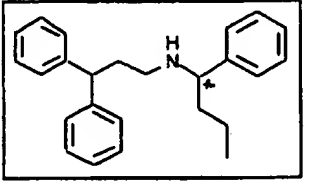
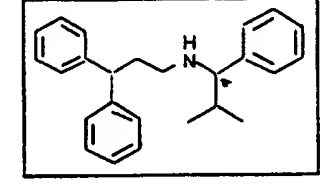
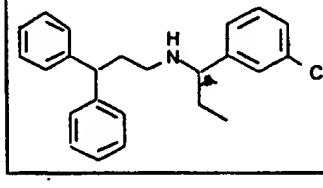
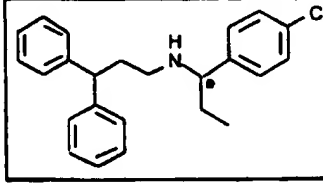
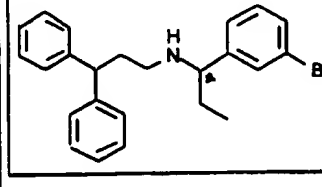
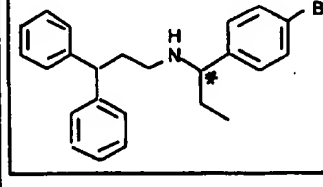
69

|   |   |   |
|---|---|---|
| <br>Compound 130   | <br>Compound 131   | <br>Compound 132   |
| <br>Compound 133   | <br>Compound 134   | <br>Compound 135   |
| <br>Compound 136   | <br>Compound 137   | <br>Compound 138   |
| <br>Compound 139 | <br>Compound 140 | <br>Compound 141 |
| <br>Compound 142 | <br>Compound 143 | <br>Compound 144 |
| <br>Compound 145 | <br>Compound 146 | <br>Compound 147 |
| <br>Compound 148 | <br>Compound 149 | <br>Compound 150 |

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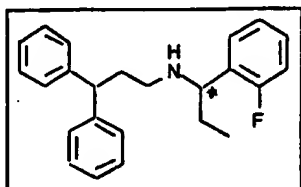
70

|   |   |   |
|---|---|---|
|    |    |    |
| Compound 151  | Compound 152  | Compound 153  |
|    |    |    |
| Compound 154  | Compound 155  | Compound 156  |
|  |  |  |
| Compound 157  | Compound 158  | Compound 159  |
|  |  |  |
| Compound 160  | Compound 161  | Compound 162  |

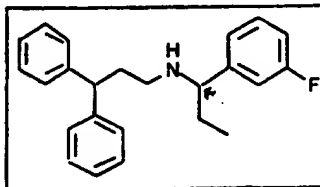
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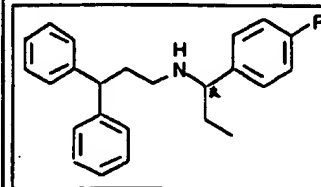
71



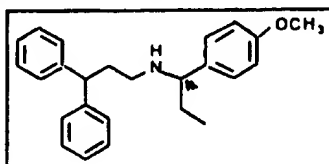
Compound 163



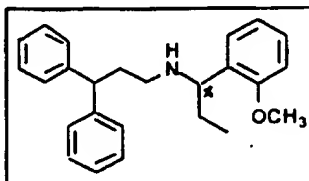
Compound 164



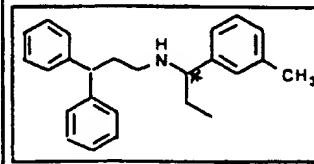
Compound 165



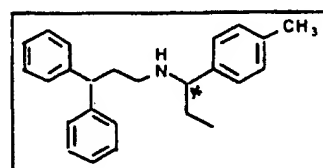
Compound 166



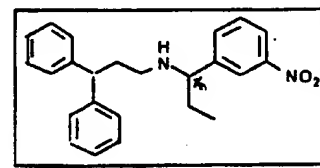
Compound 167



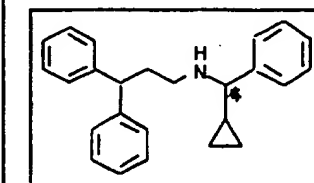
Compound 168



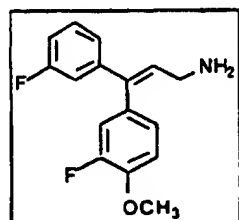
Compound 169



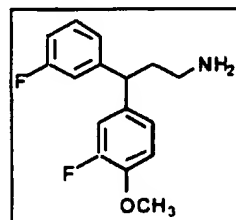
Compound 170



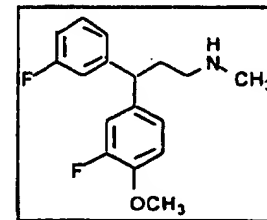
Compound 171



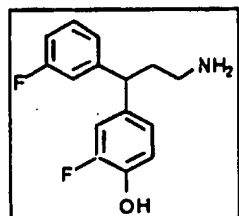
Compound 172



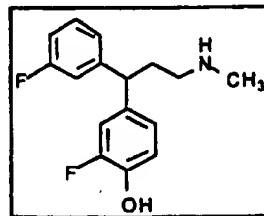
Compound 173



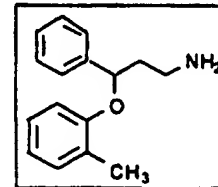
Compound 174



Compound 175



Compound 176

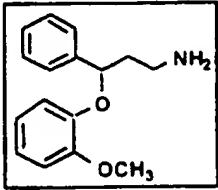
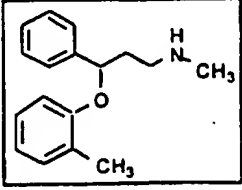
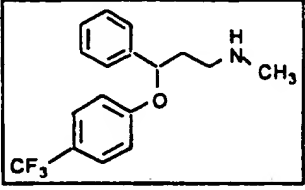
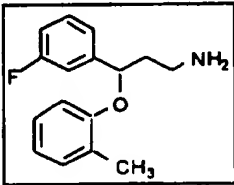
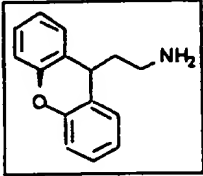
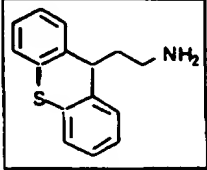
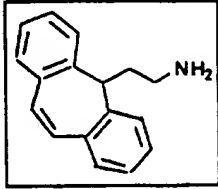
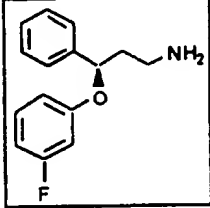
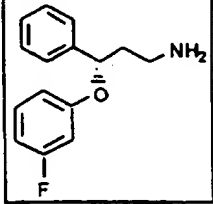
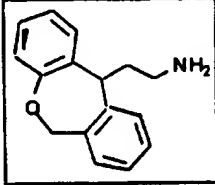
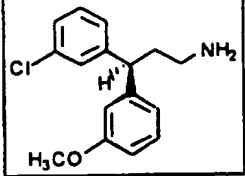
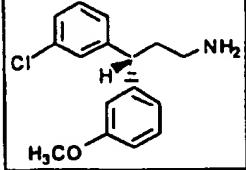
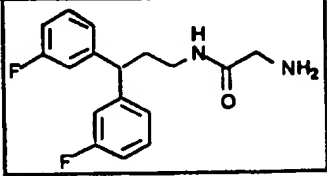
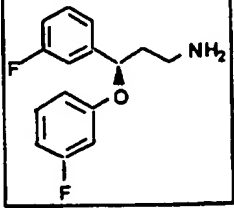
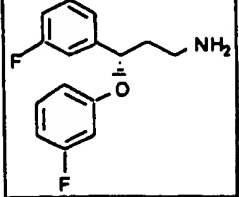


Compound 177

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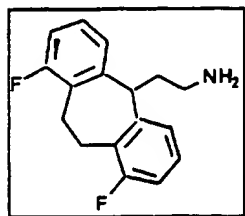
72

|   |   |  |
|---|---|--|
|    |    |                   |
| Compound 178  | Compound 179  | Compound 180   |
|    |    |                   |
| Compound 181  | Compound 182  | Compound 183   |
|   |   | Compound 186<br> |
| Compound 184  | Compound 185  | Compound 186   |
|  |  |                 |
| Compound 187  | Compound 188  | Compound 189   |
|  |  |                 |
| Compound 190  | Compound 191  | Compound 192   |

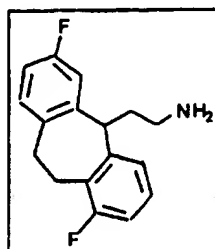
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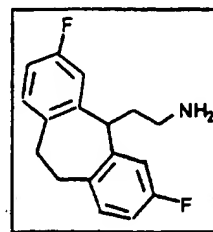
73



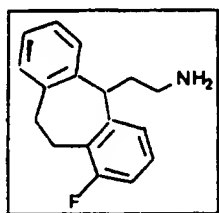
Compound 193



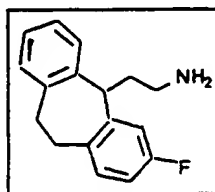
Compound 194



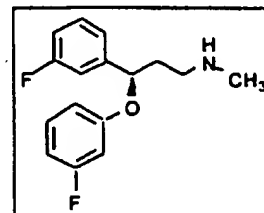
Compound 195



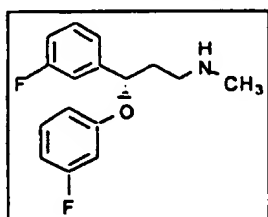
Compound 196



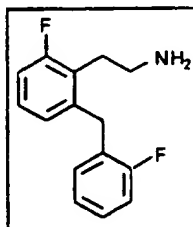
Compound 197



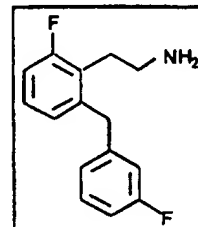
Compound 198



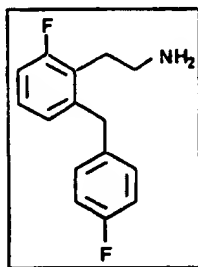
Compound 199



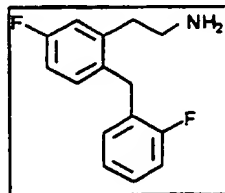
Compound 200



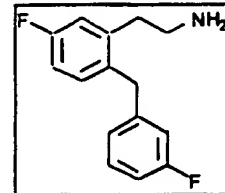
Compound 201



Compound 202



Compound 203

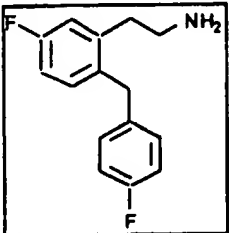
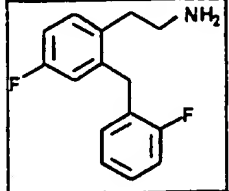
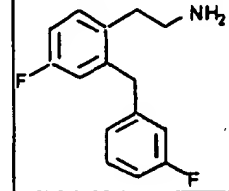
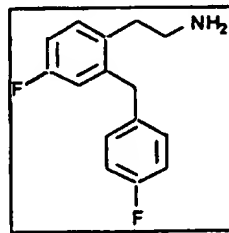
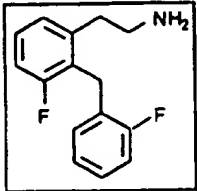
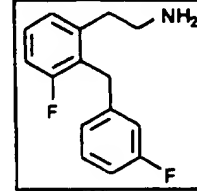
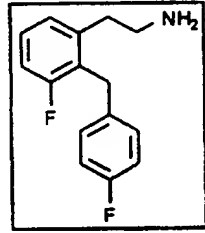
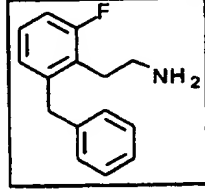
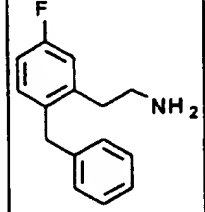
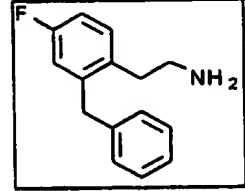
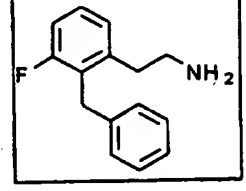


Compound 204

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|   |   |  |
|---|---|--|
|    |    |   |
| Compound 205  | Compound 206  | Compound 207   |
|    |    |   |
| Compound 208  | Compound 209  | Compound 210   |
|   |   |  |
| Compound 211  | Compound 212  | Compound 213   |
|  |  |  |
| Compound 214  | Compound 215  |  |

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Other features and advantages of the invention will be apparent from the following description of the preferred embodiments thereof, and from the claims.



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### Description of the Preferred Embodiments

The following is a detailed description of the methods and tests by which therapeutically useful compounds can be identified and utilized for the treatment of neurological disorders and diseases. The tests are exemplified by use of Compound 1, Compound 2 or Compound 3, but other compounds which have similar biological activity in these assays can also be used (as discovered) to improve on the tests. Lead compounds such as Compound 1, Compound 2 or Compound 3 can be used for molecular modeling using standard procedures, or existing or novel compounds in natural product libraries can be screened by the methods described below.

One key method is the means by which compounds can be quickly screened with standard radioligand binding techniques (a radiolabeled arylalkylamine binding assay) to identify those which bind at the same site on receptor-operated  $\text{Ca}^{2+}$  channels as Compound 1, Compound 2 or Compound 3. Data from such radioligand binding studies will also confirm that said compounds do not inhibit [ $^3\text{H}$ ]arylalkylamine binding via an action at the known sites on receptor-operated  $\text{Ca}^{2+}$  channels (such as the glutamate binding site, glycine binding site, MK-801 binding site,  $\text{Zn}^{2+}$  binding site,  $\text{Mg}^{2+}$  binding site, sigma binding site, or polyamine binding site on the NMDA receptor-ionophore complex). This screening test allows vast numbers of potentially useful compounds to be identified and screened for activity in the other assays. Those skilled in the art will recognize that other rapid assays for detection of binding to the

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arylalkylamine site on receptor-operated  $\text{Ca}^{2+}$  channels can be devised and used in this invention.

Additional testing utilizes electrophysiological (patch clamp) methodology to extend the results obtained with the above-mentioned radioligand binding assay. Such results will confirm that compounds binding to the arylalkylamine site are functional, noncompetitive antagonists of receptor-operated  $\text{Ca}^{2+}$  channels with the following properties in common with the arylalkylamines themselves: open-channel block manifested as use-dependent block, and voltage-dependent onset and reversal from block. Such results will also confirm that said compounds do not have their primary activity at the previously described sites on receptor-operated  $\text{Ca}^{2+}$  channels (such as the glutamate binding site, glycine binding site, MK-801 binding site,  $\text{Zn}^{2+}$  binding site,  $\text{Mg}^{2+}$  binding site, sigma binding site, or polyamine binding site on the NMDA receptor-ionophore complex).

In addition, recombinant DNA technology can be used to make such testing even more rapid. For example, using standard procedures, the gene(s) encoding the novel arylalkylamine binding site (i.e., receptor) can be identified and cloned. This can be accomplished in one of several ways. For example, an arylalkylamine affinity column can be prepared, and solubilized membranes from cells or tissues containing the arylalkylamine receptor passed over the column. The receptor molecules bind to the column and are thus isolated. Partial amino acid sequence information is then obtained which allows for the isolation of the gene

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encoding the receptor. Alternatively, cDNA expression libraries are prepared and subfractions of the library are tested for their ability to impart arylalkylamine receptors on cells which do not normally express such  
5 receptors (e.g., CHO cells, mouse L cells, HEK 293 cells, or *Xenopus* oocytes). In this way, the library fraction containing the clone encoding the receptor is identified. Sequential subfractionation of active library fractions and assay eventually results in a  
10 single clone encoding the arylalkylamine receptor. Similarly, hybrid-arrest or hybrid-depletion cloning can be used. *Xenopus* oocytes are injected with mRNA from an appropriate tissue or cell source (e.g., human brain tissue). Expression of the arylalkylamine receptor is  
15 detected as, for example, an NMDA- or glutamate-stimulated influx of calcium which can be blocked by Compound 1, Compound 2 or Compound 3. cDNA clones are tested for their ability to block expression of this receptor when cDNA or cRNA are hybridized to the  
20 mRNA of choice, prior to injection into *Xenopus* oocytes. The clone responsible for this effect is then isolated by the process described above. Once the receptor gene is isolated, standard techniques are used to identify the polypeptide or portion(s) thereof which is (are)  
25 sufficient for binding arylalkylamines (the arylalkylamine binding domain[s]). Further, using standard procedures, the entire receptor or arylalkylamine binding domain(s) can be expressed by recombinant technology. Said receptor or binding  
30 domain(s) can be isolated and used as a biochemical reagent such that, rather than using a competitive assay

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exemplified below, a simple direct binding assay can be used. That is, a screen is set up for compounds which bind at the novel arylalkylamine receptor. In this way large numbers of compounds can be simultaneously  
5 screened, e.g., by passage through a column containing the novel arylalkylamine receptor or arylalkylamine binding domain, and analysis performed on compounds which bind to the column.

Additional testing utilizes the combination of  
10 molecular biological techniques (expression of cloned NMDA, AMPA or nicotinic cholinergic receptors) and patch clamp electrophysiological techniques. Specifically, arylalkyl-amine analogs can be rapidly screened for potency at cloned and expressed subunits of the  
15 above-mentioned receptor-ionophore complexes. Site-directed mutagenesis can be utilized in an effort to identify which amino acid residues may be important in determining arylalkylamine potency.

**Assays for Potent and Selective Antagonists  
20 of Receptor-Operated Calcium Channels  
in the Mammalian CNS**

Desired properties of a drug include: high affinity and selectivity for receptor-operated  $\text{Ca}^{2+}$  channels, such as those present in NMDA, AMPA and  
25 nicotinic cholinergic receptor-ionophore complexes (compared to responses mediated via other neurotransmitter receptors, neurotransmitter receptor-operated ion channels, or voltage-dependent ion channels) and a noncompetitive antagonism of said  
30 receptor-operated  $\text{Ca}^{2+}$  channels.

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The NMDA receptor-ionophore complex is utilized as an example of a receptor-operated  $\text{Ca}^{2+}$  channel. Activation of the NMDA receptor opens a cation-selective channel that allows the influx of extracellular  $\text{Ca}^{2+}$  and  $\text{Na}^+$ , resulting in increases in  $[\text{Ca}^{2+}]_i$  and depolarization of the cell membrane. Measurements of  $[\text{Ca}^{2+}]_i$  were used as primary assays for detecting the activity of arylalkylamine compounds on NMDA receptors. Purified arylalkylamines, synthetic aryl-alkylamines, and synthetic analogs of arylalkylamines were examined for activity in in vitro assays capable of measuring glutamate receptor activity. Selected for detailed study were the arylalkylamines present in the venom of various spider species. The arylalkylamines present in these venoms are structurally distinct but have the basic structure of the class represented by Compounds 1 through 3. Other more simplified synthetic analogs generally consist of suitably substituted aromatic chromophoric groups attached to an alkyl(poly)amine moiety (see Compounds 19 through 215 below).

A primary assay that provides a functional index of glutamate receptor activity and that allows high-throughput screening was developed. Primary cultures of rat cerebellar granule cells loaded with the fluorimetric indicator fura-2 were used to measure changes in  $[\text{Ca}^{2+}]_i$  elicited by NMDA and its coagonist glycine. This assay provides an extremely sensitive and precise index of NMDA receptor activity. Increases in  $[\text{Ca}^{2+}]_i$  evoked by NMDA are dependent on the presence of glycine, and are blocked by extracellular  $\text{Mg}^{2+}$  or

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antagonists acting at the glutamate, glycine, or MK-801 binding sites. Increases in  $[Ca^{2+}]_i$  elicited by NMDA/glycine are readily distinguished from those resulting from depolarization by their refractoriness to inhibition by blockers of voltage-sensitive  $Ca^{2+}$  channels. The fidelity with which measurements of  $[Ca^{2+}]_i$  corroborate results obtained by electrophysiological and ligand-binding studies suggests that such measurements mirror closely activation of the NMDA receptor-ionophore complex.

**Example 1: Potent noncompetitive inhibition of NMDA receptor function**

Preferential inhibitory effects of arylalkylamines on NMDA receptor-mediated increases in  $[Ca^{2+}]_i$  in cultured rat cerebellar granule cells were measured. Increases in  $[Ca^{2+}]_i$  were elicited by the addition of NMDA/glycine (50  $\mu$ M/1  $\mu$ M) in the presence or absence of different concentrations of each test compound. The  $IC_{50}$  values were derived for each test compound using from 2 to 8 separate experiments per test compound, and the standard error level was less than 10% of the mean value for each compound.

All of the arylalkylamines tested blocked increases in  $[Ca^{2+}]_i$  in cerebellar granule cells elicited by NMDA/glycine. Certain arylalkylamines similar in structure to Compound 1 or Compound 2 were nearly as potent as MK-801 ( $IC_{50}$  = 34 nM) which is the most potent compound in the literature known to preferentially block NMDA receptors. Compound 3 had an  $IC_{50}$  = 2 nM, that is, 17-fold more potent than MK-801. Many of the

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arylalkylamines tested were more potent than competitive antagonists such as AP5 ( $IC_{50} = 15 \mu M$ ). The inhibitory effects of the aarylalkylamines were not overcome by increasing the concentrations of NMDA or glycine. That is, no change was observed in the  $EC_{50}$  for either NMDA or glycine. The aarylalkylamines are thus noncompetitive antagonists at the NMDA receptor-ionophore complex, and act neither at the glutamate nor the glycine binding sites.

**Example 2: Activity against Kainate and AMPA receptor function**

Measurements of  $[Ca^{2+}]_i$  in cerebellar granule cells can also be used to monitor activation of the native kainate or AMPA receptors present in this tissue. Although the increases in  $[Ca^{2+}]_i$  evoked by these agonists are of a lesser magnitude than those evoked by NMDA/glycine, such responses are robust and can be used to precisely assess the specificity of action of aarylalkylamines on pharmacologically defined glutamate receptor subtypes. Comparative measurements of  $[Ca^{2+}]_i$  revealed a clear distinction in the receptor selectivity of the aarylalkylamines. Some, like JSTX-3 (Joro Spider toxin from the spider *Nephila clavata*), were more potent antagonists of responses elicited by kainate ( $100 \mu M$ ) or AMPA ( $30 \mu M$ ). On the other hand, aarylalkylamines within the two structural classes defined by Compound 1 and by Compound 2 were found to inhibit preferentially responses evoked by NMDA (showing about a 100-fold difference in potency). Thus, aarylalkylamines such as Compound 1 and Compound 2 are potent and selective

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inhibitors of NMDA receptor-mediated responses in cerebellar granule cells.

**Example 3: Patch clamp electrophysiology studies**

Patch clamp electrophysiological studies on  
5 isolated cortical or hippocampal neurons from adult rat  
brain have provided additional insight into the  
mechanism of action of Compound 1, Compound 2 and  
Compound 3. These studies revealed potent and selective  
inhibitory effects of arylalkylamines on responses  
10 mediated by NMDA receptors. Thus, compounds such as  
Compound 1 blocked responses to NMDA at nanomolar  
concentrations without affecting the responses to  
kainate. These results, which show selective inhibitory  
effects of the arylalkylamines in cortical and  
15 hippocampal neurons, indicate that the arylalkylamines  
target NMDA receptors in different regions within the  
mammalian CNS. Moreover, it was found that the  
inhibitory effects of these compounds were use- and  
voltage-dependent. This strongly suggests that these  
20 compounds are blocking the open channel and, by this  
action, behave as noncompetitive NMDA receptor  
antagonists. Importantly, however, the arylalkylamines  
could be distinguished from both  $Mg^{2+}$  and MK-801,  
especially with respect to the voltage-dependence of  
25 their onset of action and reversibility of effect.

**Example 4: Radioligand binding assays**

Radioligand binding studies have demonstrated  
that arylalkylamines such as Compound 1 and Compound 2  
have a unique site of action. Although they act like



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MK-801 in some respects (noncompetitive open-channel blockade, discussed above), they fail to displace [<sup>3</sup>H]MK-801 binding at concentrations that completely block NMDA receptor-mediated responses. Assays such as these also demonstrate that the arylalkylamines do not bind with high affinity to the known MK-801, Mg<sup>2+</sup>, or polyamine binding sites on the NMDA receptor-ionophore complex. Neither do the arylalkylamines bind directly to either the glutamate, glycine or sigma binding sites at concentrations that block NMDA receptor-mediated responses. [<sup>3</sup>H]Compound 2 was synthesized as a radioligand for use in binding studies to further explore the mechanism of action of Compound 2 and particularly for use in a high-throughput screen to assess the activity of other analogs and to detect new lead structures. A similar approach was taken for [<sup>3</sup>H]Compound 5. It is clear that compounds like Compound 1 and Compound 2 target a site on the NMDA receptor-ionophore complex for which no other known compounds presently exist. The novel site of action of the arylalkylamines at the molecular level translates into pronounced therapeutic advantages at the behavioral level. As described below, the arylalkylamines possess a quite different behavioral profile from other noncompetitive antagonists of the NMDA receptor.

**Example 5: Synaptic transmission studies**

The above findings demonstrate that certain arylalkylamines, specifically those related in structure to Compound 1 and Compound 2, act through a novel mechanism and site of action to potently and selectively

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inhibit NMDA receptor-mediated responses on neurons from several different brain areas. To further assess the selective inhibitory actions of the arylalkylamines, their effects on synaptic transmission mediated by NMDA or AMPA receptors were assessed.

Glutamate-mediated transmission at synapses of Schaffer collateral fibers and CA1 pyramidal cells was measured in slices of rat brain containing the hippocampus. This assay measures electrophysiologically the postsynaptic depolarization caused by the presynaptic release of glutamate, and can readily distinguish synaptic transmission mediated by NMDA or AMPA receptors. Arylalkylamines like Compound 1, Compound 2 and Compound 3 were again found to exert preferential inhibitory effects on NMDA receptor-mediated responses, and depressed responses mediated by AMPA receptors only at much higher concentrations. For example, Compound 1 had an  $IC_{50}$  for the NMDA receptor-mediated response of 20  $\mu M$ , but an  $IC_{50}$  for the AMPA receptor-mediated response of 647  $\mu M$ . These results show that arylalkylamines can selectively inhibit synaptic transmission mediated by NMDA receptors. Other naturally occurring arylalkylamines present in the venom of *Agelenopsis aperta* likewise exert potent and selective inhibitory effects on NMDA receptor-mediated responses in the rat hippocampus.

In the aggregate, then, the results of these various studies are complementary and together identify a structurally novel class of compounds with potent and selective inhibitory activity on NMDA receptors in the mammalian CNS. Additionally, these compounds target a

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unique site on the NMDA receptor-ionophore complex. Compound 1, Compound 2 and Compound 3 were selected for additional study in a variety of *in vitro* and *in vivo* assays that model therapeutically important endpoints.

#### 5      **Neuroprotectant activity**

Desired properties of a neuroprotectant drug include the following. (1) The drug can be administered by oral or injectable routes (*i.e.*, it is not significantly broken down in the stomach, intestine or  
10      vascular system and thus reaches the tissues to be treated in a therapeutically effective amount). Such drugs are easily tested in rodents to determine their bioavailability. (2) The drug exhibits neuroprotectant activity (*i.e.*, efficacy) when given after an ischemic  
15      insult (stroke, asphyxia) or traumatic injury (head trauma, spinal cord injury). (3) The drug is devoid of or has minimal side effects such as impairment of cognition, disruption of motor performance, sedation or hyperexcitability, neuronal vacuolization,  
20      cardiovascular activity, PCP-like abuse potential, or PCP-like psychotomimetic activity.

Although glutamate is the physiological synaptic transmitter, chronic exposure to glutamate leads to neuronal cell death. Much of the  
25      neurodegeneration caused by glutamate appears to be mediated by NMDA receptors and results directly from chronically elevated levels of cytosolic  $Ca^{2+}$ . There is now extensive experimental support for the view that NMDA and AMPA receptors play a major role in mediating  
30      the neuronal degeneration following a stroke and other

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ischemic/hypoxic events (Choi, Glutamate neurotoxicity and diseases of the nervous system. *Neuron* 1: 623, 1988). Most of this evidence is based on the ability of competitive or noncompetitive antagonists of the NMDA or  
5 AMPA receptor to effectively block neuronal cell death in both *in vitro* and *in vivo* models of stroke. Compound 1, Compound 2 and Compound 4 were therefore examined for neuroprotectant effects in standard assays designed to detect such activity.

10 **Example 6: Cortical neuron protection**

To assess the *in vitro* neuroprotectant effect of arylalkylamines, mouse cortical neurons grown in culture were exposed for 5 minutes to NMDA, and cell death after 24 hours was monitored by measuring the  
15 release of lactate dehydrogenase (LDH), a cytoplasmic enzyme that is released from dying cells (Choi et al., *J. Neurosci.* 7: 357, 1987). Exposure to NMDA killed about 80% of the cortical neurons. Compound 1 or Compound 2,  
20 included along with NMDA, prevented cell death with  $IC_{50}$  values of 70  $\mu M$  and 30  $\mu M$ , respectively. The effective concentrations of the arylalkylamines are higher than those of other noncompetitive NMDA receptor antagonists, but similar to those of competitive antagonists. The  
25 effective concentrations of NMDA receptor antagonists vary depending on the particular experimental conditions and the type of cell studied (cortical, hippocampal, striatal). This neuroprotectant effect likely results from the ability of these compounds to block the influx  
30 of extracellular  $Ca^{2+}$  triggered by the NMDA receptor.

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More rigorous testing to determine potential therapeutic efficacy involved in vivo stroke models. In these models, the blood supply is temporarily blocked by clamping the main arteries to the brain. Two in vivo models of this sort were used to determine the ability of Compound 1, Compound 2 and Compound 4 to prevent neuronal cell loss.

**Example 7: Bilateral carotid artery occlusion**

The first assay was the bilateral common carotid artery occlusion model of forebrain ischemia performed in the gerbil (Karpiak et al., Animal models for the study of drugs in ischemic stroke. *Ann. Rev. Pharmacol. Toxicol.* 29: 403, 1989; Ginsberg and Busto, Rodent models of cerebral ischemia. *Stroke* 20: 1627, 1989). Blood flow to the brain was interrupted for 7 minutes by clamping the carotid arteries. The test compounds were administered as a single dose given intraperitoneally (i.p.) 30 minutes after reinstating blood flow. During the course of these experiments, the core body temperature of the animals was maintained at 37°C to prevent any hypothermic reaction. It has been shown that many NMDA receptor antagonists cause hypothermia and this effect can account for much of the protective effect of these compounds. The brains were examined for neuronal cell death 4 days later by silver staining sections of the brain and quantifying death by morphometric analysis. Compound 2 (20 mg/kg) significantly ( $p < 0.05$ ) protected against neuronal cell death in all areas of the brain examined (region CA1 of hippocampus, striatum and neocortex). Doses as low as 1

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mg/kg afforded complete (>98%) protection of the striatum. The degree of protection is comparable to that achieved with similar doses of the noncompetitive NMDA antagonist, MK-801.

5                   In subsequent experiments, Compound 1 (10 mg/kg) produced a 23% reduction in the amount of neuronal death in region CA1 of the gerbil hippocampus measured at 7 days post-ischemia, while Compound 4 (10 mg/kg) provided 90% protection.

10   **Example 8: Middle cerebral artery occlusion**

                  The middle cerebral artery model of stroke performed in the rat (Karpiak et al., Animal models for the study of drugs in ischemic stroke. *Ann. Rev. Pharmacol. Toxicol.* 29: 403, 1989; Ginsberg and Busto, 15   Rodent models of cerebral ischemia. *Stroke* 20: 1627, 1989) is different from the gerbil model because it results in a more restricted brain infarct, and thereby approximates a different kind of stroke (focal thrombotic stroke). In the first study using this 20   stroke model, one cerebral artery was permanently occluded by surgical ligation. The test compounds were administered 30 minutes after the occlusion by a single intraperitoneal (i.p.) injection. During the course of these experiments, the core body temperature of the 25   animals was maintained at 37°C to prevent any hypothermic reaction. Brains were assessed histologically for neuronal cell loss 24 hours later. Infarct volumes were calculated using the area of histological pallor from 10 slides and integrating the 30   distance between each successive section. A single dose

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(30 mg/kg) of Compound 1 was found to significantly ( $p < 0.05$ ) protect against neuronal cell loss equally as well as a maximally effective dose (10 mg/kg) of MK-801 (approximately 15% protection). Preliminary studies  
5 with Compound 2 (20 mg/kg) indicated a similar trend.

In the second study of focal cerebral ischemia in the rat, the middle cerebral artery was permanently occluded by passing a small piece of suture thread through the carotid artery to the region of the middle  
10 cerebral artery. Core body temperature was maintained at 37°C. Compound 4, 10 mg/kg i.p. administered immediately after the onset of the ischemic event, produced a statistically significant reduction in the volume of the brain infarct (20%) recorded 24 hr later.

15 In a third model of focal cerebral ischemia in the rat, an ischemic infarct was produced by a photothrombotic method using the dye Rose Bengal. Compound 4, 10 mg/kg i.p. administered 30 min after the ischemic event, produced a 20% reduction in the volume  
20 of the infarct, similar to that seen with the noncompetitive NMDA receptor antagonist, MK-801.

In a fourth model of focal cerebral ischemia in the rat, the middle cerebral artery was temporarily occluded by passing a small piece of suture thread  
25 through the carotid artery to the region of the middle cerebral artery. The suture thread was withdrawn after an ischemic period of 2 hr. Core body temperature was maintained at 37°C. Compound 4 administered at 10 mg/kg i.p. immediately after the onset of the ischemic event,  
30 produced a statistically significant reduction in the volume of the brain infarct (37%) recorded 72 hr later.

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Several important features of the lead compounds emerge from these *in vivo* results. First, and most importantly, Compound 1, Compound 2 and Compound 4 demonstrate neuroprotectant effects in several different *in vivo* models of stroke. The gerbil assay is a model for transient global cerebral ischemia and hypoxia such as cardiac arrest or perinatal hypoxia. The rat assays are models of permanent and temporary focal cerebral ischemia. The finding that Compound 1 and Compound 4 are neuroprotective in the permanent focal stroke models is surprising because the accessibility of the drug to the site of infarction is limited to the penumbral region which generally is not large. Nonetheless, Compound 1 and Compound 4 significantly ( $p < 0.05$ ) limited the extent of damage. Second, the compounds are effective when administered after the ischemic event. This is important because there is believed to be a "window of opportunity" following an infarct during which drugs may effectively halt necrotic damage. How long this time is in humans has not been defined precisely, and will likely vary depending upon the type of infarct. The essential observation, however, is that these compounds can prevent the spread of neuronal cell death once the degenerative process has commenced. Finally, Compounds 1, 2, and 4 are effective when administered parenterally, demonstrating that they penetrate the blood-brain barrier.

**Anticonvulsant activity**

Desired properties of an anticonvulsant drug include: the drug can be administered by oral or



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injectable routes, the drug exhibits effective anticonvulsant activity against several seizure types, including, but not limited to, simple partial seizures, complex partial seizures, status epilepticus, and  
5 trauma-induced seizures such as occur following head injury, including head surgery; and the drug is devoid of or has minimal side effects such as impairment of cognition, disruption of motor performance, sedation or hyperexcitability, neuronal vacuolization,  
10 cardiovascular activity, PCP-like abuse potential, or PCP-like psychotomimetic activity.

Glutamate is the major excitatory transmitter in the brain, and thus may play a major role in seizure activity, and contribute to the pathogenesis of  
15 epilepsy. Much of the evidence favoring a major role for glutamate receptors in epilepsy derives from pharmacological studies demonstrating that glutamate receptor agonists elicit seizures, and that NMDA and AMPA receptor antagonists are effective anticonvulsants  
20 when administered *in vivo*. There are numerous *in vivo* models involving different kinds of seizures and behavioral effects that are relevant for clinically distinct forms of epilepsy. It is thus prudent to test for effects in several models, because it may be an  
25 oversimplification to suppose that the same mechanism underlies all forms of seizure activity.

**Example 9: Convulsant blocking activity**

In initial studies, the ability of arylalkylamines to block seizures induced by kainate,  
30 picrotoxin or bicuculline were examined. Each of these

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convulsants acts through a different mechanism and seizures elicited by kainate are qualitatively different from those elicited by picrotoxin or bicuculline. In these experiments, a fraction of *Agelenopsis aperta* venom containing several arylalkylamine toxins was administered intravenously (iv) 5 min before picrotoxin or bicuculline, and 5 min after kainate administration. The arylalkylamines diminished the seizures induced by all three of these agents. The effects of picrotoxin or bicuculline were so severe that all 19 control animals died within 25 minutes. In contrast, there were no deaths in the 9 animals pretreated with the arylalkylamines. In fact, only about half the animals treated with the arylalkylamines showed any convulsions at all and those symptoms abated within an hour. These results demonstrate clear anticonvulsant effects of arylalkylamines and prompted further studies using purified arylalkylamines and their analogs.

**Example 10: Seizure stimuli**

Three different seizure-inducing test paradigms were used initially in this second group of studies and arylalkylamines such as Compound 1 proved to be effective anticonvulsants in two such paradigms. The first two models used DBA/2 mice which are prone to audiogenic seizures. Seizures were elicited by sound (bell tone at 109 dBs) or the intraperitoneal (ip) administration of NMDA (56 mg/kg). The test substances were administered 15-30 min before the convulsant stimulus. The number of clonic seizures was recorded for 1 min following the audiogenic stimulus or for 15

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min following the administration of NMDA. Compound 1, Compound 2, and several other arylalkylamines such as Compound 3 and Compound 4 depressed seizures evoked by either stimulus. For example, Compound 2 had an ED<sub>50</sub> of 0.13 mg/kg s.c. for audiogenic stimulus and 0.083 mg/kg s.c. for NMDA stimulus. Similarly, the EC<sub>50</sub> for Compound 4 in the audiogenic seizure model (0.08 mg/kg) approached that for MK-801 (0.02 mg/kg). In contrast, neither Compound 1 nor Compound 2 was effective at doses up to 50 mg/kg s.c. in reducing seizures in CF-1 mice elicited by i.p. NMDA.

In a second independent series of experiments, Compound 1 and Compound 4 were found to prevent seizures induced by sound in another genetically susceptible mouse model of reflex epilepsy (Frings mice) following intraperitoneal injection with IC<sub>50</sub> values of 14.3 mg/kg and ~15 mg/kg, respectively. These compounds were considerably more potent against audiogenic seizures in Frings mice following intracerebroventricular (i.c.v.) injection, with IC<sub>50</sub> values of 0.63 µg (Compound 1) and 4.77 µg (Compound 4). Compound 1 was also found to be effective against seizures elicited by maximal electroshock in CF1 mice at a dose of 4 µg i.c.v.

In further studies using the genetically susceptible mouse model of reflex epilepsy (Frings mice), Compound 9, Compound 12 and Compound 14, administered by i.c.v. injection, prevented sound-induced seizures with IC<sub>50</sub> values of 4.77 µg, 12.2 µg and 13.9 µg, respectively.

These collective findings demonstrate that arylalkylamines such as Compound 1, Compound 2 and

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Compound 4 are effective in preventing epileptic (audiogenic) and nonepileptic (chemoconvulsant) seizures. This generalized pattern of activity suggests that arylalkylamines are clinically useful in controlling seizure activity. In addition, the potency of Compound 1, Compound 2 and especially Compound 4 in *in vivo* models of seizure activity shows that these compounds can have the therapeutically relevant effects when administered parenterally in low doses, and are especially potent when administered directly into the cerebral ventricles.

#### Analgesic activity

Desired properties of an analgesic drug include: the drug can be administered by oral or injectable routes, the drug exhibits analgesic activity, the drug is devoid of or has minimal side effects such as impairment of cognition, disruption of motor performance, sedation or hyperexcitability, neuronal vacuolization, cardiovascular activity, PCP-like abuse potential, or PCP-like psychotomimetic activity.

Glutamate and NMDA receptor-mediated responses may play a role in certain kinds of pain perception (Dickenson, A cure for wind up: NMDA receptor antagonists as potential analgesics. *Trends Pharmacol. Sci.* 11: 302, 1990). The possible analgesic effects of Compound 1, Compound 2, Compound 3 and Compound 4 were therefore examined.

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**Example 11: Writhing response test**

In the first series of experiments, the animals were administered an unpleasant stimulus (2-phenyl-1,4-benzoquinone, PBQ) which elicits a writhing response (abdominal stretching). Typically, the number of writhes occurring in a 5 min observation period is recorded. Classic analgesic drugs, such as morphine, are effective at decreasing the number of PBQ-elicited writhes (100% block of the writhing response at 4 mg/kg i.p.). Nonsteroidal antiinflammatory agents are likewise effective in this model. Compound 1 (2 mg/kg), Compound 2 (2 mg/kg) and Compound 3 (1 mg/kg) depressed the writhing response by greater than 95% when administered s.c. or i.p. 30 minutes before PBQ. These results demonstrate that Compound 1, Compound 2 and Compound 3 alleviate visceral pain.

In a similar series of studies, Compound 1 and Compound 4 were found to inhibit acetic acid-induced writhing in mice following i.p. injection with  $IC_{50}$  values of 10 mg/kg and 1 mg/kg, respectively.

**Example 12: Hot plate test**

Compound 1 was tested for analgesic activity in an additional assay. In this model of analgesic activity, mice were administered test substances s.c. 30 min before being placed on a hot plate (50°C). The time taken to lick the feet or jump off the plate is an index of analgesic activity, and effective analgesics increase the latency to licking or jumping. Morphine (5.6 mg/kg) increased the latency to jump by 765%.

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Compound 1 was likewise effective in this assay and, at doses of 4 and 32 mg/kg, increased the latency to foot licking by 136% and the latency to jumping by 360%, respectively.

5                   It is noteworthy that the analgesic effects of Compound 1 in the hot plate assay were not accompanied by a decreased performance in the inverted grid assay (see below). This shows that the increase in the latency to jump off the hot plate does not simply  
10 reflect impaired motor capabilities. Together, these data suggest that Compound 1 possesses significant analgesic activity.

                  In a later series of experiments, Compound 1 and Compound 4 were demonstrated to possess significant  
15 analgesic activity in rats when administered by the intrathecal (i.th.) route. In these experiments, a 52°C hot plate was used as the nociceptive stimulus. Compound 1 (0.3 - 3 nmol) and Compound 4 (0.3 - 3 nmol) produced dose- and time-dependent antinociceptive  
20 effects; these arylalkylamines were similar to morphine (0.3 - 3 nmol) in terms of potency and efficacy. The NMDA receptor antagonist, MK-801, on the other hand, was ineffective in this assay (3-30 nmol).

### Example 13. Tail flick test

25                   In this standard assay, the thermal nociceptive stimulus was 52°C warm water with the latency to tail flick or withdrawal taken as the endpoint. Compound 1 (0.3 - 3 nmol) and Compound 4 (0.3 - 3 nmol) produced a dose- and time-dependent analgesic  
30 effect following i.th. administration. These

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arylalkylamines were similar to morphine (0.3 - 3 nmol) in terms of potency and efficacy. The NMDA receptor antagonist, MK-801, on the other hand, was ineffective in this assay (3-30 nmol).

5     **Example 14. Formalin test**

Male Sprague-Dawley rats were habituated to an observation chamber for at least 1 hr before receiving an injection of dilute formalin (5%) in a volume of 50  $\mu$ l into the left rear paw. Behavioral responses were  
10     monitored immediately after s.c. injection of formalin into the dorsal surface of the paw by counting the number of flinches exhibited by the animal. Behaviors were monitored for at least 50 min after formalin injection and were recorded as early phase responses  
15     (0 - 10 min post-formalin) and late phase responses (20 - 50 min post-formalin). Compounds were injected intrathecally (i.th.) 10 min prior to formalin (pre-treatment) or 10 min after formalin (post-treatment) in a volume of 5  $\mu$ l.

20     Intraplantal administration of formalin produced a typical biphasic response of flinching behavior, commonly described as the early and late phase responses. Intrathecal administration of Compound 1 (0.3 - 10 nmol) or Compound 4 (0.3 - 10 nmol) given as a  
25     pretreatment to formalin effectively inhibited both early- and late-phase flinching behaviors. This effect of pretreatment with the arylalkylamines was similar to that seen with pretreatment with morphine (1 - 10 nmol) or MK-801 (1 - 30 nmol).

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Compound 1 (0.3 - 10 nmol i.th.) administered after the formalin produced some inhibition of late-phase flinching, though significance was achieved only at the 10 nmol dose. Compound 4 (0.3 - 10 nmol i.th.) administered after the formalin produced significant inhibition of late-phase flinching, with significance achieved at the 3 and 10 nmol doses. This analgesic profile of activity of the arylalkylamines is similar to that seen with post-formalin administration of morphine (1 - 10 nmol); post-formalin administration of MK-801 (1 - 30 nmol), however, failed to affect late-phase flinching.

Taken together, the results obtained with the hot plate, tail flick and formalin assays demonstrate that arylalkylamines such as Compound 1 and Compound 4 have significant analgesic activity in several rodent models of acute pain. The formalin assay additionally demonstrates that arylalkylamines are effective in an animal model of chronic pain. Importantly, the arylalkylamines possess significant analgesic activity when administered after the formalin stimulus. This profile of activity clearly distinguishes the arylalkylamines from standard NMDA receptor antagonists such as MK-801.

#### Side effects of arylalkylamines

Given the important role NMDA receptors play in diverse brain functions, it is not surprising to find that antagonists of this receptor are typically associated with certain unwelcome side effects. In fact, it is this property that provides the major



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obstacle to developing therapies that target NMDA receptors. The principal side effects, which characterize both competitive and noncompetitive antagonists, are a PCP-like psychotomimetic activity, impairment of motor performance, sedation or hyperexcitability, impairment of cognitive abilities, neuronal vacuolization, or cardiovascular effects (Willetts et al., The behavioral pharmacology of NMDA receptor antagonists. *Trends Pharmacol. Sci.* 11: 423, 1990; Olney et al., Pathological changes induced in cerebrocortical neurons by phencyclidine and related drugs. *Science* 244: 1360, 1989). The psychotomimetic effect associated with inhibition of NMDA receptor-mediated responses is epitomized in the response to phencyclidine (PCP) or "angel dust" which acts at the MK-801 binding site. Impairment of cognitive ability is associated with the important role that NMDA receptors normally play in learning and memory.

Relatively less is known concerning the side effect profile of AMPA receptor antagonists. However, it is becoming clear that such compounds also elicit motor impairment, ataxia and profound sedation.

The activity of arylalkylamines was examined in animal models that index motor impairment, sedation and psychotomimetic activity as well as both *in vitro* and *in vivo* models of learning and memory.

(a) **PCP-like Psychotomimetic Activity**

In rodents, both competitive and noncompetitive antagonists of the NMDA receptor produce

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a PCP-like stereotypic behavior characterized by hyperactivity, head-weaving, and ataxia (Willetts et al., The behavioral pharmacology of NMDA receptor antagonists. *Trends Pharmacol. Sci.* 11: 423, 1990; 5 Snell and Johnson, In: *Excitatory Amino Acids in Health and Disease*, John Wiley & Sons, p. 261, 1988). We investigated whether the arylalkylamines would elicit such behaviors. In addition, we investigated whether the arylalkylamines would substitute for PCP in rats 10 trained to discriminate PCP from saline (Willetts et al., The behavioral pharmacology of NMDA receptor antagonists. *Trends Pharmacol. Sci.* 11: 423, 1990), and whether the arylalkylamines would elicit a PCP-like neuronal vacuolization (Olney et al., Pathological 15 changes induced in cerebrocortical neurons by phencyclidine and related drugs. *Science* 244: 1360, 1989).

**Example 15: Locomotor activity**

The first assay simply monitors locomotor 20 activity during the first hour following peripheral (s.c. or i.p.) administration of test substance. Mice received a dose of Compound 1 15 min before being placed into activity chambers. Activity was quantified by counting the number of breaks in a phototube grid in a 25 60 min period. In this assay, MK-801 (0.25 mg/kg p.o.) causes a 2- to 3-fold increase in locomotor activity. However, Compound 1, even when tested at 32 mg/kg s.c., did not elicit hyperactivity and, in fact, tended to depress it. This result, using a purified 30 arylalkylamine in mice, complements earlier results

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obtained in rats where the entire  
arylalkylamine-containing fraction from *Agelenopsis*  
*aperta*, when injected intravenously, did not elicit a  
PCP-like behavioral syndrome but seemed to produce a  
5 mild sedative effect.

**Example 16: Motor impairment**

In the first assay for generalized motor  
impairment, Compound 1 was examined in the inverted grid  
assay. In this assay, animals are placed on a  
10 wire-holed grid suspended from a rotating metal bar  
which can be inverted. The animals are then scored for  
their ability to climb to the top or hang on to the  
grid. Animals with severe motor impairment fall off the  
grid. This assay provides an index of "behavioral  
15 disruption" that may result from ataxia, loss of the  
righting reflex, sedation, or muscle relaxation. In  
these tests, Compound 1, administered at 32 mg/kg s.c.,  
did not lessen the ability of DBA/2 mice to right  
themselves when the grid was inverted ( $p > 0.05$ ).  
20 Compound 2 was likewise without effect ( $p > 0.05$ ) on  
motor performance in DBA/2 mice when administered at a  
dose of 20 mg/kg s.c. These doses are considerably  
higher than those required to prevent sound-induced  
seizures in DBA/2 mice (see Example 10 above).

25 The second assay of acute motor impairment was  
the rotorod assay. In this assay, Frings and CF1 mice  
were injected with test compound and placed on a knurled  
rod which rotated at a speed of 6 rpm. The ability of  
the mice to maintain equilibrium for long periods of  
30 time was determined; those mice that were unable to

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maintain equilibrium on the rotorod for 1 min in each of 3 trials were considered impaired. Compound 1 produced acute motor impairment in Frings mice with a  $TD_{50}$  (that dose which produced motor toxicity in 50% of the test animals) of 16.8 mg/kg i.p. This dose is similar to that which prevents sound-induced seizures in Frings mice (see Example 10 above). There is a much clearer separation between effective and toxic doses of Compound 1 in Frings mice, however, when the Compound is administered i.c.v. In this case, no apparent motor toxicity was evident until the dose of Compound 1 exceeded 1.56  $\mu$ g i.c.v. ( $>2$  times the  $ED_{50}$  of 0.63  $\mu$ g). Finally, motor impairment in CF1 mice was noted with Compound 1 following i.c.v. administration of 4  $\mu$ g.

Compound 4, Compound 9, Compound 12 and Compound 14 were administered to Frings mice by i.c.v. injection, and acute motor impairment was measured. The  $TD_{50}$  values for Compounds 4, 9, 12 and 14 were 8-16  $\mu$ g, 14.8  $\mu$ g, 30.2  $\mu$ g and 30.8  $\mu$ g, respectively. These  $TD_{50}$  values were 2-3 times higher than the effective  $IC_{50}$  values for anticonvulsant potency (see Example 10 above); a clear separation between effective and toxic doses was noted.

**Example 17. PCP discrimination**

In this assay, rats who have been trained to lever press for food reinforcement must select which of two levers in their cages is correct. The only stimulus they have for selecting the correct lever is their ability to detect whether they received a PCP or vehicle injection. After about two months of training, rats

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become very good at discriminating PCP from vehicle injections and can then be tested with other drugs to determine if they are discriminated as PCP. When tested in this procedure, other drugs which are known to  
5 produce a PCP-like intoxication substitute for PCP. These drugs include various PCP analogs such as ketamine and the noncompetitive NMDA receptor antagonist, MK-801.

Compound 1 (1 - 30 mg/kg i.p.) did not substitute for PCP, and thus was completely devoid of  
10 PCP-like discriminative stimulus effects. At 30 mg/kg i.p., only 1 of the 7 animals tested responded at all on either lever. It is thus clear that a behaviorally effective dosage range of Compound 1 was evaluated. As the ability of test compounds to produce PCP-like  
15 effects in rats is believed to be predictive of their ability to produce PCP-like psychotomimetic activity and abuse liability in humans, these results strongly suggest that the arylalkylamines such as Compound 1 will lack such deleterious side effects in man.

#### 20 Example 18

The administration of compounds such as PCP and MK-801 to rats produces a neurotoxic effect termed neuronal vacuolization. Following a single dose of such compounds, vacuoles are found in particular central  
25 neurons, especially those in the cingulate cortex and retrosplenial cortex. No such vacuolization was present in rats treated with Compound 1 at the single high dose of 100 mg/kg i.p.

Taken together, the results on locomotor  
30 activity, motor impairment, PCP discrimination and

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neuronal vacuolization strongly suggest that arylalkylamines will be devoid of PCP-like side effects in man.

**(b) Cognitive impairment**

5           One of the major reasons for postulating a role of NMDA receptors in memory and learning derives from cellular studies on long-term potentiation (LTP) in the rat hippocampus. LTP is a long-lasting increase in the magnitude of synaptic responses produced by brief  
10 yet intense synaptic stimulation. Since the discovery of this phenomenon, it has become the preeminent cellular model of learning in the vertebrate brain (Teyler and Discenna, Long-term potentiation. *Annu. Rev. Neurosci.* 10: 131, 1987). Transmission at synapses  
15 formed by Schaffer collaterals onto CA1 pyramidal cells is mediated by NMDA and AMPA receptors. Following a brief tetanizing stimulus, the magnitude of the population spike (a measure of synaptic transmission) is greatly increased and remains so for hours. It has been  
20 shown that all known competitive and noncompetitive antagonists of NMDA receptors block LTP in the rat hippocampus, whereas antagonists of non-NMDA receptors are without effect (Collingridge and Davis, In: *The NMDA Receptor*, IRL Press. p. 123, 1989). This supports a  
25 role of NMDA receptors in memory and learning.

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**Example 19: LTP assay**

The effects of selected arylalkylamines and literature standards were examined for effects on LTP in slices of rat hippocampus. As anticipated, all the conventional competitive (AP5 and AP7) and noncompetitive (MK-801 and ifenprodil) NMDA receptor antagonists inhibited the induction of LTP in the hippocampus. Slices of rat hippocampus were superfused for 30-60 min with a test compound before delivering a tetanizing stimulus consisting of 3 trains, separated by 500 msec, of 100 Hz for 1 sec each. The response amplitude was monitored for an additional 15 minutes post-tetanus. The tetanizing stimulus caused a mean 95% increase in the amplitude of the synaptic response. The induction of LTP was significantly blocked ( $p < 0.05$ ) by competitive (AP5, AP7) or noncompetitive (MK-801, ifenprodil) NMDA receptor antagonists. Quite surprisingly, none of the arylalkylamines tested (Compound 1, Compound 2, Compound 3 and others) blocked the induction of LTP ( $p > 0.05$ ), even when used at high concentrations (100-300  $\mu\text{M}$ ) that caused some inhibition of the control response.

These results highlight yet another unique and important feature of arylalkylamines. Arylalkylamines are the first, and at present the only, class of compounds shown to be selective and potent antagonists of the NMDA receptor that do not block the induction of LTP. This likely reflects the novel mechanism and site of action of arylalkylamines and suggests that drugs which target the novel site on the NMDA receptor will similarly lack effects on LTP. As LTP is the primary

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cellular model for learning and memory in the mammalian CNS, it additionally suggests that such drugs will lack deleterious effects on cognitive performance.

**Example 20: Learning tests**

5 Preliminary experiments using one of the more potent synthetic arylalkylamine analogs, Compound 3, in an *in vivo* learning paradigm demonstrate that these drugs lack effects on cognitive performance. In this test, rats were trained to alternate turning in a T maze  
10 for a food reward. MK-801 was included for comparison. Test compounds were administered i.p. 15 min before testing. Control animals made the correct choice about 80% of the time. Increasing doses of MK-801 progressively decreased the number of correct choices  
15 and this decrement in behavior was accompanied by hyperactivity. In contrast, Compound 3 did not impair the ability of the animals to make the correct choices ( $p > 0.05$ ). At the highest doses tested, Compound 3 caused some decrease in locomotor activity, exactly the  
20 opposite effect observed with MK-801.

Although MK-801 decreased learning performance in parallel with increases in locomotor activity, other studies using different paradigms in rodents and primates have shown a clear dissociation between the  
25 effects on learning and locomotion. Thus, both competitive and noncompetitive NMDA receptor antagonists impair learning at doses which do not cause any overt change in motor behavior. This demonstrates that conventional NMDA receptor antagonists impair learning  
30 independently of other side effects. The results of the



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T-maze assay demonstrate that Compound 3, and other arylalkylamines, do not impair learning even at doses that cause some decrease in locomotor activity.

One additional observation emerged from these learning tests. The animals' first response on the second day of testing was random and was therefore not dependent on the last response of the previous day's testing. Control animals thus correctly made the first choice about 50% of the time. MK-801 has no effect on this first choice. However, animals administered Compound 3 on the previous day made the first choice correctly considerably more often. Unlike control animals then, the animals treated with Compound 3 behaved as if they remembered the last choice of the previous day.

In a second series of experiments, the effect of Compound 4 on learning in the Morris water maze task was evaluated. In this test, a hidden platform was placed in a fixed location in a circular steel tank, and submerged 2 cm below the surface of the water. Each rat was given 3 trials per day with a 10 min intertrial interval for 5 days. A trial was initiated by placing the rat in the water, nose facing the wall of the tank, at one of three predetermined starting locations. The order of the start location was varied daily. Learning was measured as a decrease in time required to swim to the platform. If an animal failed to locate the platform within 60 sec after the start of the trial, the rat was hand-guided to it. The animals remained on the platform for 10 sec before being removed from the tank. Ten min after the last training trial on day 5, the

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animals received a probe test. The platform was removed for this 1 trial task and the animals were allowed to swim for 60 sec to assess the spatial bias for the platform location. Two measures were recorded from this task: latency to first crossing the area where the platform had been, and total number of crossings. A total of 5 injections of Compound 4 were given to each rat. In the first series of experiments, Compound 4 was administered at 10 mg/kg i.p. daily for 5 days. This treatment regimen impaired learning; however, these animals experienced significant weight loss and unusual behavioral signs ("shivering," motor impairment, difficulty in swimming) with repeated dosing of Compound 4. In a subsequent study, six animals received 1 mg/kg i.p. for the first 4 days of training, while two animals received 5 mg/kg i.p. during this period. On the last day of training, both groups received 10 mg/kg. Neither the 1 mg/kg nor the 5 mg/kg animals showed any impairment in learning the location of the hidden platform, nor did the final 10 mg/kg dose produce any impairment in the ability of the animal to perform the already learned task.

The results of these learning tasks are encouraging. They suggest that arylalkylamines lack the learning and memory deficits that typify other NMDA receptor antagonists. In fact, there is a suggestion that the arylalkylamines may even be nootropic (memory enhancers).

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**(c) Cardiovascular effects**

In vivo studies with certain arylalkylamines revealed a hypotensive effect of these compounds, especially at high doses. On the basis of these results, a systematic study of the effects of arylalkylamines on cardiovascular function was performed.

**Example 21:  $\text{Ca}^{2+}$  channel inhibition**

We have discovered that some of the arylalkylamines are quite potent inhibitors of voltage-sensitive  $\text{Ca}^{2+}$  channels, specifically those sensitive to inhibition by dihydropyridines (L-type channels). Such effects on vascular smooth muscle would be expected to dilate blood vessels and cause a drop in blood pressure, thus producing hypotension.

The ability of arylalkylamines to inhibit dihydropyridine-sensitive  $\text{Ca}^{2+}$  channels was examined in cerebellar granule cells and a rat aortic smooth muscle cell line, Ar5 cells. In cerebellar granule cells, Compound 2 inhibited depolarization-induced increases in  $[\text{Ca}^{2+}]_i$  at concentrations 100-fold higher than those required to block responses to NMDA ( $\text{IC}_{50}$  values of 24  $\mu\text{M}$  and 161 nM, respectively). Overall, we have observed a wide range of potencies against voltage-sensitive  $\text{Ca}^{2+}$  channels that does not correlate with potency against NMDA receptors. This strongly suggests that further structure-activity work based on chemical modification of the arylalkylamine molecule will lead to the development of compounds that are very potent NMDA antagonists with low potency against voltage-sensitive  $\text{Ca}^{2+}$  channels. Indeed, Compound 1 (with an  $\text{IC}_{50}$  of 102 nM

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against NMDA receptor-mediated responses in cerebellar granule cells) is a relatively poor inhibitor of voltage-sensitive  $\text{Ca}^{2+}$  channels in cerebellar granule cells ( $\text{IC}_{50} = 257 \mu\text{M}$ ) and is virtually without effect on voltage-sensitive  $\text{Ca}^{2+}$  influx in A<sub>v</sub>r5 cells ( $\text{IC}_{50} = 808 \mu\text{M}$ ).

Arylalkylamines are not, however, indiscriminate blockers of voltage-sensitive  $\text{Ca}^{2+}$  channels. They do not, for example, affect voltage-sensitive  $\text{Ca}^{2+}$  channels in cerebellar Purkinje cells (P-type channels) or those channels thought to be involved in neurotransmitter release (N-channels). The arylalkylamines that do block voltage-sensitive  $\text{Ca}^{2+}$  channels appear to target specifically L-type  $\text{Ca}^{2+}$  channels. Moreover, as mentioned above, there is a high degree of structural specificity in this effect. For example, one arylalkylamine is 57 times more potent than another arylalkylamine in blocking  $\text{Ca}^{2+}$  influx through L-type channels, where the only structural difference between the compounds is the presence or absence of a hydroxyl group.

**Example 22: In vivo cardiovascular studies**

The arylalkylamines Compound 1 and Compound 2 produce moderate drops (20-40 mm Hg) in mean arterial blood pressure (MABP) in anesthetized rats at doses which are effective in the in vivo stroke models (10-30 mg/kg s.c.). The hypotensive effect of Compound 4 has been evaluated in greater detail. Compound 4 elicited a marked drop (40 mm Hg) in mean arterial pressure which persisted for approximately 90-120 min when administered

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at the dose of 10 mg/kg i.p.; it was in this same group of rats that Compound 4 afforded significant neuroprotection in the suture model of middle cerebral artery occlusion (see Example 8 above). Similar results were obtained in the rat study in which Compound 4 demonstrated neuroprotectant activity in the Rose Bengal photothrombotic model of focal ischemic stroke (see Example 8 above). Further studies using the pithed rat preparation strongly suggest that the hypotensive activity of Compound 4 is a peripherally mediated effect. The hypotension and bradycardia produced by Compound 4 was maintained in rats pretreated with atropine, suggesting that these effects are not mediated by a cholinergic mechanism. Similarly, Compound 4 elicited hypotension and bradycardia in chemically sympathectomized rats (pretreated with a ganglionic blocker), suggesting that these effects are not mediated via the sympathetic nervous system.

On the basis of these findings, it is anticipated that chemical efforts will minimize the cardiovascular side effects by (1) enhancing the uptake of arylalkylamine into the brain such that lower doses are required for neuroprotection, and (2) increasing the selectivity (potency ratio) of arylalkylamines for receptor-operated  $\text{Ca}^{2+}$  channels over voltage-sensitive  $\text{Ca}^{2+}$  channels.

**Example 23: Biological activity of Compound 19 and analogs**

Compounds 19 - 215 had high potencies against NMDA-induced increases in  $[\text{Ca}^{2+}]_i$  in rat cerebellar

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granule cells grown in culture (Table 1). The inhibitory effect of Compound 19 on responses to NMDA was noncompetitive. Compounds 19 - 215 inhibited [<sup>3</sup>H]MK-801 binding in membranes prepared from rat hippocampal and cortical tissue (Table 1).

Compound 19 possessed the following additional biological activities: significant ( $p < 0.05$  compared to control) anticonvulsant activity against maximal electroshock-induced seizures in mice following i.p. administration ( $ED_{50} = 26.4$  mg/kg and  $TD_{50}$  (rotorod) = 43.8 mg/kg); significant anticonvulsant activity against maximal electroshock-induced seizures in mice following oral (p.o.) administration ( $ED_{50} = 35$  mg/kg), but with motor impairment at 30 mg/kg; significant analgesic activity in the hot-plate and PBQ-induced writhing assays at 16 mg/kg i.p.; no PCP-like stereotypic behavior (hyperexcitability and head weaving) at 30 mg/kg i.p. in rats; no generalization to PCP in the PCP discrimination assay in rats at doses up to the behaviorally active dose of 30 mg/kg i.p. Compound 19 was significantly less potent in antagonizing increases in  $[Ca^{2+}]_i$  elicited by depolarizing concentrations of KCl in rat cerebellar granule cells ( $IC_{50} = 10.2$   $\mu$ M), and was without effect on blood pressure when administered s.c. in rats at doses up to 100 mg/kg. Compound 19, however, did block the induction of LTP in rat hippocampal slices when tested at 100  $\mu$ M.

Compound 20 possessed the following additional biological activities: significant anticonvulsant activity against maximal electroshock-induced seizures in mice following i.p. administration ( $ED_{50} = 20.1$  mg/kg

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and  $TD_{50}$  (rotorod) = 20.6 mg/kg); no significant anticonvulsant activity against maximal electroshock-induced seizures in mice following oral (p.o.) administration at doses up to 30 mg/kg, but with motor impairment at 30 mg/kg; significant anticonvulsant activity against sound-induced seizures in a genetically susceptible mouse model of reflex epilepsy (Frings mice) following i.p. ( $ED_{50}$  = 2.1 mg/kg and  $TD_{50}$  = 19.9 mg/kg) and oral ( $ED_{50}$  = 9.7 mg/kg and  $TD_{50}$  = 21.8 mg/kg) administration; significant anticonvulsant activity against maximal electroshock-induced seizures in rats following oral administration with an  $ED_{50}$  value of 33.64 mg/kg and an  $TD_{50}$  value of 55.87 mg/kg; an increase in seizure threshold as indexed by the i.v. Metrazol test in mice at the dose of 10 mg/kg i.p.; significant neuroprotectant activity in a rat model of temporary focal ischemia (a 51% reduction in the infarct volume following the administration of two doses of 1 mg/kg i.p., the first given immediately after middle cerebral artery occlusion and the second given 6 hr later; a 43% reduction in the infarct volume following the administration of two doses of 1 mg/kg i.p., the first given 2 hr after middle cerebral artery occlusion (i.e., at the time of reperfusion) and the second given 6 hr later); significant neuroprotectant activity (a 24% reduction in the infarct volume) in a rat model of permanent focal ischemia following the administration of 1 mg/kg i.p. at 30 min and again 4 hr post-occlusion; significant neuroprotectant activity (a 50% reduction in the infarct volume) in a rat photothrombotic model of focal ischemia following the administration of 10 mg/kg

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i.p. at 15 min, 3 hr, and again 6 hr post-occlusion; no significant analgesic activity at the dose of 25 mg/kg i.p. in the rat 52°C hot plate test or the rat 48°C tail flick test; significant analgesic activity, not blocked by the opiate receptor antagonist naloxone, in the rat formalin test at the dose of 10 mg/kg i.p.; significant analgesic activity, not blocked by naloxone, against acetic acid-induced abdominal writhing in mice at the dose of 10 mg/kg i.p.; no generalization to PCP in the PCP discrimination assay in rats at doses up to the behaviorally active dose of 10 mg/kg i.p.; no neuronal vacuolization in rats when administered at doses of 10 and 30 mg/kg i.p.; no significant cardiovascular activity in anesthetized rats at doses up to 15  $\mu$ moles/kg i.v. or 10 mg/kg i.p.; no significant cardiovascular activity in conscious beagle dogs at doses of 0.3 or 1 mg/kg i.v. (60 sec bolus injection); transient increases in mean arterial pressure and heart rate in conscious beagle dogs at the dose of 3 mg/kg i.v., with larger magnitude and longer duration effects seen at the dose of 10 mg/kg i.v. (60 sec bolus injection); increased motor activity, agitation and anxiousness, slight tremors, licking of the mouth, whining, and urination in conscious beagle dogs at the dose of 3 mg/kg i.v. (60 sec bolus injection); dilated pupils, whole body tremors, incoordination, licking of the mouth, salivation, panting, rapid blinking of the eyes, whining, anxiousness, seizures, and death in conscious beagle dogs at the dose of 10 mg/kg i.v. (60 sec bolus injection); no behavioral effects in conscious male NMRI mice at the doses of 2 and 4 mg/kg i.p.;



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excitation and increased reactivity to touch in  
conscious male NMRI mice at the dose of 8 mg/kg i.p.;  
excitation, Straub tail, tremor, stereotypies,  
hypothermia, and mydriasis in conscious male NMRI mice  
5 at the doses of 16 and 32 mg/kg i.p.; convulsions and  
death in conscious male NMRI mice at the dose of  
64 mg/kg i.p.; convulsions and death in conscious male  
NMRI mice at the doses of 128 and 256 mg/kg i.p.; no  
behavioral effects in conscious male Wistar rats at the  
10 dose of 2 mg/kg i.v.; excitation, stereotypies,  
increased reactivity to touch, increased muscle tone,  
and tremor in conscious male Wistar rats at doses  
ranging from 4 to 16 mg/kg i.v.; Straub tail,  
convulsions, and death in conscious male Wistar rats at  
15 the dose of 32 mg/kg i.v.

Compound 21 possessed the following additional  
biological activities: significant anticonvulsant  
activity against sound-induced seizures in a genetically  
susceptible mouse model of reflex epilepsy (Frings mice)  
20 following i.p. administration ( $ED_{50}$  = 3.41 mg/kg and  $TD_{50}$   
(motor impairment) = 15.3 mg/kg).

Compound 33 (an enantiomer of Compound 21)  
possessed the following additional biological  
activities: significant anticonvulsant activity against  
25 sound-induced seizures in a genetically susceptible  
mouse model of reflex epilepsy (Frings mice) following  
i.p. administration ( $ED_{50}$  = 4.6 mg/kg and  $TD_{50}$  (motor  
impairment) = 27.8 mg/kg); significant anticonvulsant  
activity against maximal electroshock-induced seizures  
30 in rats following oral administration at the dose of  
25 mg/kg, with no motor toxicity apparent at this dose;

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significant neuroprotectant activity in a rat model of focal ischemic stroke following i.p. administration of 2 mg/kg 30 min prior to vessel occlusion and 2 mg/kg 3 hr post-occlusion; no significant analgesic activity at the dose of 25 mg/kg i.p. in the rat 52°C hot plate test or the rat 48°C tail flick test; significant analgesic activity in a rat model of chronic neuropathic pain following i.th. administration of doses ranging from 15 to 80  $\mu$ g; significant analgesic activity in a rat model of chronic neuropathic pain following i.p. administration of doses of 3-10 mg/kg; no neuronal vacuolization when administered to rats at the dose of 30 mg/kg i.p.; no significant cardiovascular activity in anesthetized rats at doses up to 3 mg/kg i.v.; no significant cardiovascular activity in conscious beagle dogs at the dose of 0.3 mg/kg i.v. (60 sec bolus injection); transient increases in mean arterial pressure in conscious beagle dogs at the dose of 1 mg/kg i.v., with larger magnitude and longer duration effects seen at the doses of 3 and 10 mg/kg i.v. (60 sec bolus injection); a transient increase in heart rate in conscious beagle dogs at the dose of 10 mg/kg i.v. (60 sec bolus injection); licking of the mouth in conscious beagle dogs at the dose of 3 mg/kg i.v. (60 sec bolus injection); dilated pupils, whole body tremors, incoordination, licking of the mouth, salivation, and panting in conscious beagle dogs at the dose of 10 mg/kg i.v. (60 sec bolus injection); no significant drug-induced changes in the ECG in conscious beagle dogs at doses up to 10 mg/kg i.v. (60 sec bolus injection); no behavioral effects in conscious male NMRI

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mice at the doses of 2 and 4 mg/kg i.p.; excitation, increased reactivity to touch, and hypothermia in conscious male NMRI mice at the dose of 8 mg/kg i.p.; excitation, Straub tail, tremor, jumping, stereotypies, hypothermia, and mydriasis in conscious male NMRI mice at the doses of 16 and 32 mg/kg i.p.; convulsions in conscious male NMRI mice at the dose of 64 mg/kg i.p.; convulsions and death in conscious male NMRI mice at the doses of 128 and 256 mg/kg i.p.

10                   Compound 34 (an enantiomer of Compound 21) possessed the following additional biological activities: significant anticonvulsant activity against sound-induced seizures in a genetically susceptible mouse model of reflex epilepsy (Frings mice) following  
15 i.p. administration ( $ED_{50}$  = 22 mg/kg and  $TD_{50}$  (motor impairment) between 10 and 15 mg/kg); hyperthermia in conscious male NMRI mice at the dose of 2 mg/kg i.p.; no behavioral effects in conscious male NMRI mice at the dose of 4 mg/kg i.p.; excitation, increased reactivity  
20 to touch, and hypothermia in conscious male NMRI mice at the dose of 8 mg/kg i.p.; excitation, Straub tail, tremor, jumping, stereotypies, hypothermia, and mydriasis in conscious male NMRI mice at the doses of 16 and 32 mg/kg i.p.; convulsions in conscious male NMRI  
25 mice at the dose of 64 mg/kg i.p.; convulsions and death in conscious male NMRI mice at the doses of 128 and 256 mg/kg i.p.

Compound 22 possessed the following additional biological activities: significant anticonvulsant  
30 activity against sound-induced seizures in a genetically susceptible mouse model of reflex epilepsy (Frings mice)

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following i.p. ( $ED_{50}$  = 4.9 mg/kg and  $TD_{50}$  (inverted grid)  
= 26.8 mg/kg) and oral ( $ED_{50}$  = 5.1 mg/kg and  $LD_{50}$  =  
18.3 mg/kg) administration; and no significant  
cardiovascular activity in anesthetized rats at doses up  
5 to 15  $\mu$ moles/kg (4.47 mg/kg) i.v.

Compound 50 (an enantiomer of Compound 22)  
possessed the following additional biological  
activities: significant anticonvulsant activity against  
sound-induced seizures in a genetically susceptible  
10 mouse model of reflex epilepsy (Frings mice) following  
i.p. administration ( $ED_{50}$  = 2.7 mg/kg and  $TD_{50}$  (motor  
impairment) = 17.4 mg/kg); significant anticonvulsant  
activity against sound-induced seizures in a genetically  
susceptible mouse model of reflex epilepsy (Frings mice)  
15 following p.o. administration ( $ED_{50}$  = 9.0 mg/kg and  $TD_{50}$   
(motor impairment) = 18.9 mg/kg); significant  
anticonvulsant activity against maximal  
electroshock-induced seizures in rats following oral  
administration with  $ED_{50}$  = 28 mg/kg and  $TD_{50}$  = 20 mg/kg;  
20 significant neuroprotectant activity in a rat model of  
focal ischemic stroke following i.p. administration of  
2 mg/kg 30 min prior to vessel occlusion and 2 mg/kg  
3 hr post-occlusion; no significant analgesic activity  
at the dose of 25 mg/kg i.p. in the rat 52°C hot plate  
25 test or the rat 48°C tail flick test; and no significant  
cardiovascular activity in anesthetized rats at doses up  
to 5 mg/kg i.v.

Compound 51 (an enantiomer of Compound 22)  
possessed the following additional biological  
30 activities: significant anticonvulsant activity against  
sound-induced seizures in a genetically susceptible

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mouse model of reflex epilepsy (Frings mice) following i.p. administration ( $ED_{50}$  = 9.1 mg/kg and  $TD_{50}$  (motor impairment) = 13.6 mg/kg).

Compound 24 possessed the following additional biological activities: significant anticonvulsant activity against sound-induced seizures in a genetically susceptible mouse model of reflex epilepsy (Frings mice) following i.p. administration ( $ED_{50}$  = 5 mg/kg and  $TD_{50}$  (motor impairment) = 16 mg/kg); significant anticonvulsant activity against maximal electroshock-induced seizures in rats following oral administration with  $ED_{50}$  = 46 mg/kg and  $TD_{50}$  = 51 mg/kg; no significant neuroprotectant activity in a rat model of focal ischemic stroke following i.p. administration of 2 mg/kg 30 min prior to vessel occlusion and 2 mg/kg 3 hr post-occlusion; and no significant cardiovascular activity in anesthetized rats at doses up to 10 mg/kg i.v.

Compound 25 possessed the following additional biological activities: significant anticonvulsant activity against maximal electroshock-induced seizures in mice following i.p. administration with an  $ED_{50}$  = 12.47 mg/kg and a  $TD_{50}$  = 32.18 mg/kg; significant anticonvulsant activity against maximal electroshock-induced seizures in rats following oral administration with an  $ED_{50}$  = 46.43 mg/kg and a  $TD_{50}$  between 163 and 326 mg/kg.

Compound 31 possessed the following additional biological activities: significant anticonvulsant activity against sound-induced seizures in a genetically susceptible mouse model of reflex epilepsy (Frings mice)

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following i.p. administration ( $ED_{50}$  = 6 mg/kg and  $TD_{50}$  (motor impairment) between 10 and 20 mg/kg).

Compound 46 possessed the following additional biological activities: significant anticonvulsant activity against sound-induced seizures in a genetically susceptible mouse model of reflex epilepsy (Frings mice) following i.p. administration ( $ED_{50}$  = 25 mg/kg and  $TD_{50}$  (motor impairment) between 18 and 21 mg/kg); and no significant neuroprotectant activity in a rat model of focal ischemic stroke following i.p. administration of 2 mg/kg 30 min prior to vessel occlusion and 2 mg/kg 3 hr post-occlusion.

Compound 57 possessed the following additional biological activities: significant anticonvulsant activity against sound-induced seizures in a genetically susceptible mouse model of reflex epilepsy (Frings mice) following i.p. administration ( $ED_{50}$  = 1 mg/kg and  $TD_{50}$  (motor impairment) between 6 and 8 mg/kg).

Compound 58 possessed the following additional biological activities: significant anticonvulsant activity against sound-induced seizures in a genetically susceptible mouse model of reflex epilepsy (Frings mice) following i.p. administration ( $ED_{50}$  = 0.9 mg/kg and  $TD_{50}$  (motor impairment) = 14.5 mg/kg); no significant neuroprotectant activity in a rat model of focal ischemic stroke following i.p. administration of 2 mg/kg 30 min prior to vessel occlusion and 2 mg/kg 3 hr post-occlusion; and no significant cardiovascular activity in anesthetized rats at doses up to 2 mg/kg i.v.

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Compound 59 possessed the following additional biological activities: significant anticonvulsant activity against sound-induced seizures in a genetically susceptible mouse model of reflex epilepsy (Frings mice) following i.p. administration ( $ED_{50}$  = 2.7 mg/kg and  $TD_{50}$  (motor impairment) = 7.8 mg/kg); a reduction in seizure threshold as indexed by the i.v. Metrazol test in mice at the dose of 11.7 mg/kg i.p.; no significant neuroprotectant activity in a rat model of focal ischemic stroke following i.p. administration of 2 mg/kg 30 min prior to vessel occlusion and 2 mg/kg 3 hr post-occlusion; and no significant cardiovascular activity in anesthetized rats at doses up to 10 mg/kg i.v.

Compound 60 possessed the following additional biological activities: significant anticonvulsant activity against sound-induced seizures in a genetically susceptible mouse model of reflex epilepsy (Frings mice) following i.p. administration ( $ED_{50}$  = 4.4 mg/kg and  $TD_{50}$  (motor impairment) = 9.2 mg/kg); significant anticonvulsant activity against sound-induced seizures in a genetically susceptible mouse model of reflex epilepsy (Frings mice) following oral administration ( $ED_{50}$  = 10 mg/kg and  $TD_{50}$  (motor impairment) = 25.6 mg/kg); significant anticonvulsant activity against maximal electroshock-induced seizures in mice following i.p. administration ( $ED_{50}$  = 8.17 mg/kg and  $TD_{50}$  (rotorod) = 17.30 mg/kg); no effect on seizure threshold as indexed by the i.v. Metrazol test in mice at the doses of 1 and 4 mg/kg i.p.; a reduction in seizure threshold as indexed by the i.v. Metrazol test in mice at the

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doses of 8 and 17 mg/kg i.p.; significant neuroprotectant activity in a rat model of temporary focal ischemic stroke following i.p. administration of 2 mg/kg 30 min prior to vessel occlusion and 2 mg/kg 3 hr post-occlusion; significant neuroprotectant activity in a rat model of temporary focal ischemic stroke following i.p. or i.v. administration of 1 mg/kg 2 hr and again 8 hr post-occlusion; significant neuroprotectant activity in a rat model of temporary focal ischemic stroke following i.v. administration of 1 mg/kg 2 hr post-occlusion; no significant neuroprotectant activity in a rat photothrombotic model of focal ischemia following the administration of 10 mg/kg i.p. at 15 min, 3 hr, and again 6 hr post-occlusion; no neuronal vacuolization when administered at doses of 20 mg/kg i.p. or 10 mg/kg i.v.; no significant cardiovascular activity in conscious beagle dogs at the dose of 0.3 mg/kg i.v. (60 sec bolus injection); transient increases in mean arterial pressure in conscious beagle dogs at the doses of 1 and 3 mg/kg i.v., with larger magnitude and longer duration effects seen at the dose of 10 mg/kg i.v. (60 sec bolus injection); transient increases in heart rate in conscious beagle dogs at the doses of 3 and 10 mg/kg i.v. (60 sec bolus injection); no significant changes in the ECG in conscious beagle dogs at doses ranging from 0.3 to 10 mg/kg i.v. (60 sec bolus injection); no significant behavioral effects in conscious beagle dogs at the doses of 0.3 and 1 mg/kg i.v. (60 sec bolus injection); a slight increase in respiratory rate in conscious beagle dogs at the dose of 3 mg/kg i.v.



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(60 sec bolus injection); dilated pupils, whole body tremors, salivation, and urination in conscious beagle dogs at the dose of 10 mg/kg i.v. (60 sec bolus injection); no significant behavioral effects in  
5 conscious male Wistar rats at doses up to 4 mg/kg i.v.; excitation, stereotypies, increased reactivity to touch, increased muscle tone, and tremor in conscious male Wistar rats at the dose of 8 mg/kg i.v.; Straub tail, convulsions, and death in conscious male Wistar rats at  
10 the dose of 16 mg/kg i.v.

Compound 119 possessed the following additional biological activities: significant anticonvulsant activity against sound-induced seizures in a genetically susceptible mouse model of reflex  
15 epilepsy (Frings mice) following i.p. administration with an  $ED_{50}$  = 7.0 mg/kg and  $TD_{50}$  (motor impairment) = 26.3 mg/kg.

Compound 120 possessed the following additional biological activities: significant  
20 anticonvulsant activity against sound-induced seizures in a genetically susceptible mouse model of reflex epilepsy (Frings mice) following i.p. administration with an  $ED_{50}$  = 4.77 mg/kg and  $TD_{50}$  (motor impairment) between 20 and 30 mg/kg.

25 Compound 122 possessed the following additional biological activities: significant anticonvulsant activity against sound-induced seizures in a genetically susceptible mouse model of reflect epilepsy (Frings mice) following i.p. administration  
30 with an  $ED_{50}$  = 4.7 mg/kg and  $TD_{50}$  (motor impairment) = 15.3 mg/kg.

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Compound 138 possessed the following additional biological activities: significant anticonvulsant activity against maximal electroshock-induced seizures in mice following i.p. administration with an ED<sub>50</sub> = 51.9 mg/kg and TD<sub>50</sub> (motor impairment) = 100.7 mg/kg.

Compound 151 possessed the following additional biological activities: significant anticonvulsant activity against maximal electroshock-induced seizures in mice following i.p. administration with an ED<sub>50</sub> = 36.5 mg/kg and TD<sub>50</sub> (motor impairment) = 108.4 mg/kg; a significant increase in seizure threshold as indexed by the i.v. Metrazol test in mice at the doses of 36.5 and 108 mg/kg i.p.

Compound 156 possessed the following additional biological activities: significant anticonvulsant activity against sound-induced seizures in a genetically susceptible mouse model of reflect epilepsy (Frings mice) following i.p. administration with an ED<sub>50</sub> = 5.0 mg/kg and TD<sub>50</sub> (motor impairment) = 17.4 mg/kg.

Taken together, the results obtained with these simplified synthetic arylalkylamines suggest that such simplified molecules do not interact specifically with the arylalkylamine binding site on receptor-operated Ca<sup>2+</sup> channels as do Compounds 1, 2 and 3. Specifically, Compounds 19 - 215 bind to the site labeled by [<sup>3</sup>H]MK-801 at concentrations ranging approximately 1 to 400-fold higher than those which antagonize the function of the NMDA receptor-ionophore complex. The fact that Compounds 19 - 215 at

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therapeutic doses do not generally produce PCP-like stereotypic behavior, substitute for PCP in drug discrimination assays, or elicit neuronal vacuolization suggests, however, that such compounds might be useful either as lead compounds or drug candidates for neurological disorders and diseases. It has been reported that compounds which bind with low affinity (relative to MK-801) to the site labeled by [<sup>3</sup>H]MK-801 might possess therapeutic utility and possess a more favorable side effect profile than that possessed by a high affinity antagonist such as MK-801 itself (Rogawski, Therapeutic potential of excitatory amino acid antagonists: channel blockers and 2,3-benzodiazepines. *Trends Pharmacol. Sci.* 14: 325, 1993). The low affinity of certain compounds within the group of Compounds 19 - 215 (relative to MK-801) for the site labeled by [<sup>3</sup>H]MK-801 may place these compounds into this general class of low affinity noncompetitive antagonists.

**Identification of a novel modulatory site on receptor-operated calcium channels**

Having identified arylalkylamines which have therapeutically useful properties as defined above, compounds can now be identified which act at the critical arylalkylamine binding site on receptor-operated Ca<sup>2+</sup> channels, such as those present within NMDA, AMPA and nicotinic cholinergic receptor-ionophore complexes.

Examples of suitable tests now follow:

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**Example 24: Radioligand binding in rat cortex or cerebellum.**

The following assay can be utilized as a high throughput assay to screen product libraries (e.g.,  
5 natural product libraries and compound files at major pharmaceutical companies) to identify new classes of compounds with activity at this unique arylalkylamine site. These new classes of compounds are then utilized as chemical lead structures for a drug development  
10 program targeting the arylalkylamine binding site on receptor-operated  $\text{Ca}^{2+}$  channels. The compounds identified by this assay offer a novel therapeutic approach to treatment of neurological disorders or diseases. Examples of such compounds include those  
15 provided in the generic chemical formulae above. Routine experiments can be performed to identify those compounds having the desired activities.

Rat brain membranes are prepared according to the method of Williams et al. (Effects of polyamines on  
20 the binding of [ $^3\text{H}$ ]MK-801 to the NMDA receptor: Pharmacological evidence for the existence of a polyamine recognition site. *Molec. Pharmacol.* 36: 575, 1989) with the following alterations: Male Sprague-Dawley rats (Harlan Laboratories) weighing  
25 100-200 g are sacrificed by decapitation. The cortex or cerebellum from 20 rats are cleaned and dissected. The resulting brain tissue is homogenized at 4°C with a polytron homogenizer at the lowest setting in 300 ml 0.32 M sucrose containing 5 mM K-EDTA (pH 7.0). The  
30 homogenate is centrifuged for 10 min at 1,000 x g and the supernatant removed and centrifuged at 30,000 x g

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for 30 minutes. The resulting pellet is resuspended in 250 ml 5 mM K-EDTA (pH 7.0) stirred on ice for 15 min, and then centrifuged at 30,000 x g for 30 minutes. The pellet is resuspended in 300 ml 5 mM K-EDTA (pH 7.0) and  
5 incubated at 32°C for 30 min. The suspension is then centrifuged at 100,000 x g for 30 min. Membranes are washed by resuspension in 500 ml 5 mM K-EDTA (pH 7.0), incubated at 32°C for 30 min, and centrifuged at 100,000 x g for 30 minutes. The wash procedure,  
10 including the 30 min incubation, is repeated. The final pellet is resuspended in 60 ml 5 mM K-EDTA (pH 7.0) and stored in aliquots at -80°C. The extensive washing procedure utilized in this assay was designed in an effort to minimize the concentrations of glutamate and  
15 glycine (co-agonists at the NMDA receptor-ionophore complex) present in the membrane preparation.

To perform a binding assay with [<sup>3</sup>H]arylalkylamine, aliquots of SPMS (Synaptic Plasma Membranes) are thawed, resuspended in 30 mls of 30 mM  
20 EPPS/1mM K-EDTA, pH 7.0, and centrifuged at 100,000 x g for 30 minutes. SPMS are resuspended in buffer A (30 mM EPPS/1 mM K-EDTA, pH 7.0). The [<sup>3</sup>H]arylalkylamine is added to this reaction mixture. Binding assays are carried out in polypropylene test tubes. The final  
25 incubation volume is 500 µl. Nonspecific binding is determined in the presence of 100 µM nonradioactive arylalkylamine. Duplicate samples are incubated at 0°C for 1 hour. Assays are terminated by the addition of 3 ml of ice-cold buffer A, followed by filtration over  
30 glass-fiber filters (Schleicher & Schuell No. 30) that are presoaked in 0.33% polyethyleneimine (PEI). The

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filters are washed with another 3 x 3 ml of buffer A, and radioactivity is determined by scintillation counting at an efficiency of 35-40% for  $^3\text{H}$ .

In order to validate the above assay, the following experiments are also performed:

(a) The amount of nonspecific binding of the [ $^3\text{H}$ ]arylalkylamine to the filters is determined by passing 500  $\mu\text{l}$  of buffer A containing various concentrations of [ $^3\text{H}$ ]arylalkylamine through the presoaked glass-fiber filters. The filters are washed with another 4 x 3 ml of buffer A, and radioactivity bound to the filters is determined by scintillation counting at an efficiency of 35-40% for  $^3\text{H}$ . In filters that are not pretreated with 0.33% PEI, it was found that 87% of the  $^3\text{H}$ -ligand was bound to the filter. Presoaking with 0.33% PEI reduces the nonspecific binding to 0.5 - 1.0% of the total ligand added.

(b) A saturation curve is constructed by resuspending SPMs in buffer A. The assay buffer (500  $\mu\text{l}$ ) contains 60  $\mu\text{g}$  of protein. Concentrations of [ $^3\text{H}$ ]arylalkylamine are used, ranging from 1.0 nM to 400  $\mu\text{M}$  in half-log units. A saturation curve is constructed from the data, and an apparent  $K_D$  value and  $B_{\text{max}}$  value determined by Scatchard analysis (Scatchard, The attractions of proteins for small molecules and ions. *Ann. N.Y. Acad. Sci.* 51: 660, 1949). The cooperativity of binding of the [ $^3\text{H}$ ]arylalkylamine is determined by the construction of a Hill plot (Hill, A new mathematical treatment of changes of ionic concentrations in muscle and nerve under the action of

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electric currents, with a theory to their mode of excitation. *J. Physiol.* 40: 190, 1910).

(c) The dependence of binding on protein (receptor) concentration is determined by resuspending  
5 SPMs in buffer A. The assay buffer (500  $\mu$ l) contains a concentration of [ $^3$ H]arylalkylamine equal to its  $K_D$  value and increasing concentrations of protein. The specific binding of [ $^3$ H]arylalkylamine should be linearly related to the amount of protein (receptor) present.

10 (d) The time course of ligand-receptor binding is determined by resuspending SPMs in buffer A. The assay buffer (500  $\mu$ l) contains a concentration of [ $^3$ H]arylalkylamine equal to its  $K_D$  value and 100  $\mu$ g of protein. Duplicate samples are incubated at 0°C for  
15 varying lengths of time; the time at which equilibrium is reached is determined, and this time point is routinely used in all subsequent assays.

(e) The pharmacology of the binding site can be analyzed by competition experiments. In such  
20 experiments, the concentration of [ $^3$ H]arylalkylamine and the amount of protein are kept constant, while the concentration of test (competing) drug is varied. This assay allows for the determination of an  $IC_{50}$  and an apparent  $K_D$  for the competing drug (Cheng and Prusoff,  
25 Relationship between the inhibition constant ( $K_i$ ) and the concentration of inhibitor which causes 50 percent inhibition ( $IC_{50}$ ) of an enzymatic reaction. *J. Biochem. Pharmacol.* 22: 3099, 1973). The cooperativity of  
30 binding of the competing drug is determined by Hill plot analysis.

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Specific binding of the [<sup>3</sup>H]arylalkylamine represents binding to a novel site on receptor-operated Ca<sup>2+</sup> channels such as those present within NMDA-, AMPA- and nicotinic cholinergic receptor-ionophore complexes.

5 As such, other arylalkylamines should compete with the binding of [<sup>3</sup>H]arylalkylamine in a competitive fashion, and their potencies in this assay should correlate with their inhibitory potencies in a functional assay of receptor-operated Ca<sup>2+</sup> channel antagonism (e.g.,

10 inhibition of NMDA receptor-induced increases in [Ca<sup>2+</sup>]<sub>i</sub> in cultures of rat cerebellar granule cells). Conversely, compounds which have activity at the other known sites on receptor-operated Ca<sup>2+</sup> channels (e.g., MK-801, Mg<sup>2+</sup>, polyamines) should not displace

15 [<sup>3</sup>H]arylalkylamine binding in a competitive manner. Rather, complex allosteric modulation of [<sup>3</sup>H]arylalkylamine binding, indicative of noncompetitive interactions, might be expected to occur. In preliminary experiments, MK-801 did not displace

20 [<sup>3</sup>H]arylalkylamine binding at concentrations up to 100 μM.

(f) Studies to estimate the dissociation kinetics are performed by measuring the binding of [<sup>3</sup>H]arylalkylamine after it is allowed to come to

25 equilibrium (see (d) above), and a large excess of nonradioactive competing drug is added to the reaction mixture. Binding of the [<sup>3</sup>H]arylalkylamine is then assayed at various time intervals. With this assay, the association and dissociation rates of binding of the

30 [<sup>3</sup>H]arylalkylamine are determined (Titeler, *Multiple Dopamine Receptors: Receptor Binding Studies in*



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*Dopamine Pharmacology*. Marcel Dekker, Inc., New York, 1983). Additional experiments involve varying the reaction temperature (0°C to 37°C) in order to understand the temperature dependence of this parameter.

5    **Example 25: Radioligand binding in cerebellar granule cells**

Primary cultures of cerebellar granule neurons are obtained from 8-day-old rats and plated onto squares of Aclar plastic coated with poly-L-lysine. The plastic squares are placed in 24-well culture plates, and approximately  $7.5 \times 10^5$  granule cells are added to each well. Cultures are maintained in Eagles' medium (HyClone Laboratories) containing 25 mM KCl, 10% fetal calf serum (HyClone Laboratories), 2 mM glutamine, 100 µg/ml gentamicin, 50 U/ml penicillin, and 50 µg/ml streptomycin at 37°C in a humid atmosphere of 5% CO<sub>2</sub> in air for 24 hr before the addition of cytosine arabinoside (10 µM, final). No changes of culture medium are made until the cells are used for receptor binding studies 6-8 days after plating.

To perform a binding assay with [<sup>3</sup>H]arylalkylamine, the reaction mixture consists of 200 µl of buffer A (20 mM K-HEPES, 1 mM K-EDTA, pH 7.0) in each well of the 24-well plate. The [<sup>3</sup>H]arylalkylamine is added to this reaction mixture. Nonspecific binding is determined in the presence of 100 µM nonradioactive arylalkylamine. Triplicate samples are incubated at 0°C for 1 hour. Assays are terminated by manually scraping the cells off the Aclar squares and placing them into polypropylene test tubes.

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The membranes prepared from whole cells in this manner are suspended in 10 ml of ice-cold buffer A, and filtered over glass-fiber filters (Schleicher & Schuell No. 30) that are presoaked in 0.33% PEI. The filters  
5 are washed with another 3 x 3 ml of buffer A, and radioactivity on the filters is determined by scintillation counting at an efficiency of 35-40% for  $^3\text{H}$ . The assay may be terminated by centrifugation rather than filtration in order to minimize nonspecific  
10 binding.

Specific experiments to characterize and validate the assay are performed essentially as above, except that cells are used in place of membranes for the initial binding. The binding assay allows for the  
15 determination of an  $\text{IC}_{50}$  value and an apparent  $K_D$  for the competing drug as described by Scatchard analysis (The attractions of proteins for small molecules and ions. *Ann. N.Y. Acad. Sci.* 51: 660, 1949). Cooperativity of binding of the competing drug is determined by Hill plot  
20 analysis (A new mathematical treatment of changes of ionic concentrations in muscle and nerve under the action of electric currents, with a theory to their mode of excitation. *J. Physiol.* 40: 190, 1910). The specific binding of the [ $^3\text{H}$ ]arylalkylamine represents  
25 binding to a novel site on receptor-operated calcium channels.

**Example 26: Recombinant receptor binding assay**

The following is one example of a rapid screening assay for useful compounds of this invention.  
30 In this assay, a cDNA or gene clone encoding the

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arylalkylamine binding site (receptor) from a suitable organism such as a human is obtained using standard procedures. Distinct fragments of the clone are expressed in an appropriate expression vector to produce the smallest polypeptide(s) obtainable from the receptor which retain the ability to bind Compound 1, Compound 2 or Compound 3. In this way, the polypeptide(s) which includes the novel arylalkylamine receptor for these compounds can be identified. Such experiments can be facilitated by utilizing a stably transfected mammalian cell line (e.g., HEK 293 cells) expressing the arylalkylamine receptor.

Alternatively, the arylalkylamine receptor can be chemically reacted with chemically modified Compound 1, Compound 2 or Compound 3 in such a way that amino acid residues of the arylalkylamine receptor which contact (or are adjacent to) the selected compound are modified and thereby identifiable. The fragment(s) of the arylalkylamine receptor containing those amino acids which are determined to interact with Compound 1, Compound 2 or Compound 3 and are sufficient for binding to said molecules, can then be recombinantly expressed, as described above, using a standard expression vector(s).

The recombinant polypeptide(s) having the desired binding properties can be bound to a solid phase support using standard chemical procedures. This solid phase, or affinity matrix, may then be contacted with Compound 1, Compound 2 or Compound 3 to demonstrate that those compounds can bind to the column, and to identify conditions by which the compounds may be removed from

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the solid phase. This procedure may then be repeated using a large library of compounds to determine those compounds which are able to bind to the affinity matrix, and then can be released in a manner similar to

5 Compound 1, Compound 2 or Compound 3. However, alternative binding and release conditions may be utilized in order to obtain compounds capable of binding under conditions distinct from those used for

10 arylalkylamine binding (e.g., conditions which better mimic physiological conditions encountered especially in pathological states). Those compounds which do bind can thus be selected from a very large collection of compounds present in a liquid medium or extract.

Once compounds able to bind to the

15 arylalkylamine binding polypeptide(s) described above are identified, those compounds can then be readily tested in the various assays described above to determine whether they, or simple derivatives thereof, are useful compounds for therapeutic treatment of

20 neurological disorders and diseases described above.

In an alternate method, native arylalkylamine receptor can be bound to a column or other solid phase support. Those compounds which are not competed off by reagents which bind other sites on the receptor can then

25 be identified. Such compounds define novel binding sites on the receptor. Compounds which are competed off by other known compounds thus bind to known sites, or bind to novel sites which overlap known binding sites. Regardless, such compounds may be structurally distinct

30 from known compounds and thus may define novel chemical classes of agonists or antagonist which may be useful as

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therapeutics. In summary, a competition assay can be used to identify useful compounds of this invention.

**Example 27: Patch-clamp electrophysiology assay**

The following assay is performed for selected compounds identified in the above-mentioned radioligand binding assays as interacting in a highly potent and competitive fashion at the novel arylalkylamine binding site on receptor-operated  $\text{Ca}^{2+}$  channels, such as those present in NMDA-, AMPA- or nicotinic cholinergic receptor-ionophore complexes. This patch-clamp assay provides additional relevant data about the site and mechanism of action of said previously selected compounds. Specifically, the following pharmacological and physiological properties of the compounds interacting at the arylalkylamine binding site are determined, utilizing the NMDA receptor-ionophore complex as an example of receptor-operated  $\text{Ca}^{2+}$  channels: potency and efficacy at blocking NMDA receptor-mediated ionic currents, the noncompetitive nature of block with respect to glutamate and glycine, use-dependence of action, voltage-dependence of action, both with respect to onset and reversal of blocking, the kinetics of blocking and unblocking (reversal), and open-channel mechanism of blocking. Such data confirm that the compounds interacting at the arylalkylamine binding site retain the unique biological profile of the arylalkylamines, and do not have their primary activity at the known sites on the NMDA receptor-ionophore complex (glutamate binding site, glycine binding site,

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MK-801 binding site,  $Mg^{2+}$  binding site,  $Zn^{2+}$  binding site, sigma binding site, polyamine binding site).

Patch-clamp recordings of mammalian neurons (hippocampal, cortical, cerebellar granule cells) are carried out utilizing standard procedures (Donevan et al., Arcaine blocks N-methyl-D-aspartate receptor responses by an open channel mechanism: whole-cell and single-channel recording studies in cultured hippocampal neurons. *Molec. Pharmacol.* 41: 727, 1992; Rock and Macdonald, Spermine and related polyamines produce a voltage-dependent reduction of NMDA receptor single-channel conductance. *Molec. Pharmacol.* 42: 157, 1992).

Alternatively, patch-clamp experiments can be performed on *Xenopus* oocytes or on a stably transfected mammalian cell line (e.g., HEK 293 cells) expressing specific subunits of receptor-operated  $Ca^{2+}$  channels. In this manner, for example, potency and efficacy at various glutamate receptor subtypes (e.g., NMDAR1, NMDAR2A through NMDAR2D, GluR1 through GluR4) can be determined. Further information regarding the site of action of the arylalkylamines on these glutamate receptor subtypes can be obtained by using site-directed mutagenesis.

#### 25 **Example 28: Synthesis of arylalkylamines**

Arylalkylamines such as Compound 1, Compound 2 and Compound 3 are synthesized by standard procedures (Jasys et al., The total synthesis of argiotoxins 636, 659 and 673. *Tetrahedron Lett.* 29: 6223, 1988; Nason et al., Synthesis of neurotoxic *Nephila* spider venoms:

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NSTX-3 and JSTX-3. *Tetrahedron Lett.* 30: 2337, 1989).  
Specific examples of syntheses of arylalkylamine analogs  
4-18 are provided in co-pending application U.S. Serial  
No. 08/485,038, filed June 7, 1995, and co-pending  
5 International Patent Application No. PCT/US94/12293,  
published as WO95/21612, filed October 26, 1994, hereby  
incorporated by reference herein in their entirety.

**Example 29: Synthesis of simplified arylalkylamines**

Synthesis of Compound 20 was accomplished as  
10 follows.

A solution of sodium hydride (1.21 g, 50 mmol)  
in dimethoxyethane was treated with diethyl cyanomethyl-  
phosphonate (8.86 g, 50 mmol) and the reaction stirred  
4 hr at room temperature. To this was added  
15 3,3'-difluorobenzophenone (10 g, 46 mmol) in DME. The  
reaction was stirred 24 hr at room temperature, quenched  
with H<sub>2</sub>O, and partitioned between diethyl ether and  
water. The ether fraction was dried over Na<sub>2</sub>SO<sub>4</sub> and  
concentrated. GC/MS of this material showed 90% of the  
20 product A and 10% starting benzophenone.

A solution of this material in ethanol with a  
catalytic amount of Pd(OH)<sub>2</sub> was hydrogenated at 55 psi  
hydrogen for 4 hr at room temperature. The reaction was  
filtered and the catalyst washed with ethanol (3x). The  
25 filtrate and ethanol washes were combined and  
concentrated. GC/MS of this material showed 90% of the  
product B and 10% of the starting benzophenone.

A solution of this material in THF was treated  
with 70 ml 1 M B<sub>2</sub>H<sub>6</sub> (70 mmol) in THF and refluxed 1 hr.  
30 After cooling the reaction was treated with 6 N HCl

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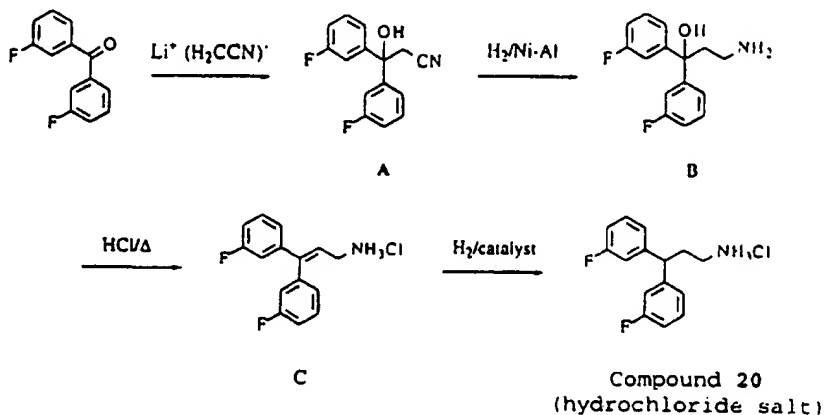
(50 ml) and refluxed an additional hour. After cooling the reaction was basified to pH 14 with 10 N NaOH and equilibrated with ether. The ether layer was removed and washed with 10% HCl (3x). The acidic washes were  
5 combined, basified to pH 14 with 10 N NaOH and extracted with dichloromethane (3x). The organic washes were combined, dried over Na<sub>2</sub>SO<sub>4</sub>, and concentrated to yield an oil. GC/MS of this material showed 100% Compound 20. GC/EI-MS (R<sub>t</sub> = 7.11 min) m/z (relative intensity) 247 (M<sup>+</sup>,  
10 31), 230 (100), 215 (30), 201 (52), 183 (63), 134 (23), 121 (16), 101 (21), 95 (15), 77 (15). This material in diethyl ether was filtered and treated with 35 ml 1 M HCl in ether. The precipitate was collected, dried, and recrystallized from water-ethanol to afford 1.045 g of  
15 Compound 20, as the hydrochloride salt. <sup>1</sup>H-NMR (CDCl<sub>3</sub>) δ 8.28 (3H, br s), 7.28-7.17 (2 H, m), 7.02-6.86 (6 H, m), 4.11 (1H, t, J=8 Hz), 2.89 (2H, br t, J=8 Hz), 2.48 (2H, br t, J=7 Hz); <sup>13</sup>C-NMR (CDCl<sub>3</sub>) δ 164.6, 161.3, 144.8, 144.7, 130.4, 130.3, 123.3, 123.2, 114.7, 114.5, 114.1,  
20 113.8, 47.4, 38.4, 32.7.



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Synthesis of Compound 21, Compound 33 and Compound 34 was accomplished as follows.

A 100 ml round-bottomed flask equipped with stir bar, septa, and argon source was charged with Compound 1 (2.43 g, 10 mmol) in 30 ml THF. The solution was cooled to  $-78^\circ\text{C}$  and treated dropwise with 11 ml lithium bis(trimethylsilyl)amide (1M in THF) (11 mmol). The reaction was stirred at  $-78^\circ\text{C}$  for 30 min and treated dropwise with excess iodomethane (3.1 ml, 50 mmol). The reaction was stirred 30 min at  $-58^\circ\text{C}$ . GC/EI-MS analysis of an aliquot from the reaction showed consumption of the starting nitrile 1. The reaction was quenched with water, diluted with diethyl ether and transferred to a separatory funnel. The ether layer was washed with 10% HCl (3X), brine (1X), dried with anhydrous  $\text{MgSO}_4$ , and concentrated to a brown oil. This material was distilled (Kugelrohr,  $100^\circ\text{C}$ ) at reduced pressure to afford 1.5 g of a clear oil. GC/EI-MS of this material showed it to contain the desired product 2, ( $R_t=7.35$  min)  $m/z$  (rel. int.) 257 ( $M^+$ , 3), 203 (100), 183 (59), 170 (5), 133 (4), 109 (3);  $^1\text{H-NMR}$

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(CDCl<sub>3</sub>) δ 7.4-6.9 (8H, m), 4.01 (1H, d, J=10 Hz), 3.38 (1H, dq, J=7, 10 Hz), 1.32 (3H, d, J=7 Hz); <sup>13</sup>C-NMR (CDCl<sub>3</sub>) δ 19.4, 30.5, 54.2, 114.5, 114.6, 114.7, 114.9, 115.0, 115.3, 123.3, 123.4, 123.6, 123.7, 130.5, 130.6, 131.7.

Product 3 was synthesized by the catalytic reduction of 2 using Raney nickel in 95:5 EtOH:aqueous sodium hydroxide (2 Eq.) under 60 psi hydrogen.

GC/EI-MS (R<sub>t</sub>=7.25 min) m/z (rel. int.) 261 (M<sup>+</sup>, 20), 244 (35), 229 (16), 215 (17), 201 (80), 183 (100), 133 (42), 115 (27), 109 (47), 95 (20); <sup>1</sup>H-NMR (CDCl<sub>3</sub>) δ 7.3-6.8 (8H, m), 3.62 (1H, d, J=10 Hz), 2.70 (1H, M), 2.40 (2H, m), 1.73 (2H, m), 0.91 (3H, d, J=7 Hz). Note that product 3 in this reaction sequence corresponds to Compound 21.

Product 2 in 10% IPA-hexane (100 mg/ml) was chromatographed, in 500 μl aliquots, through Chiral Cel OD (2.0 x 25 cm) using 10% IPA-hexane at 10 ml/min measuring optical density at 254 nm. This afforded the two optically pure enantiomers 4 and 5 (as determined by analytical chiral HPLC; Note, the stereochemistry of these two compounds has not been assigned at this time). These two compounds were identical in their GC/EI-MS and <sup>1</sup>H-NMR spectra as product 2 (data above).

Each of the enantiomers 4 and 5 was reduced separately using dimethyl sulfideborane complex in the following manner. A solution of compound (4 or 5) in THF was heated to reflux and treated with excess (2 Eq.) 1M (in THF) dimethyl sulfideborane complex and the

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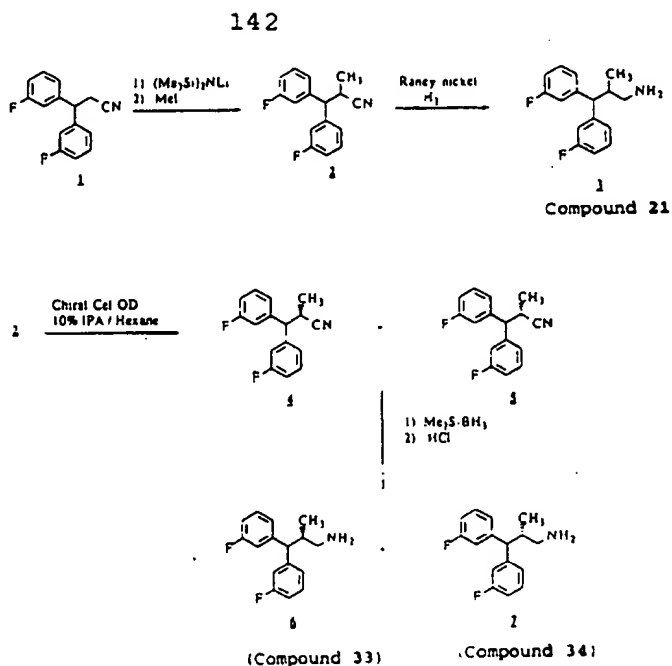
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reaction refluxed 30 min. After this time the reaction was cooled to 0°C and treated with 6 N HCl. The reaction was set to reflux for 30 min. After this time the reaction was transferred to a separatory funnel, basified to pH > 12 with 10N NaOH, and the product (6 or 7) extracted into ether. The ether layer was washed with brine, dried over anhydrous MgSO<sub>4</sub> and concentrated to an oil. The product was purified by prep-TLC using 5% methanol-chloroform. Each of the individual enantiomers (6 and 7) were found to be identical in their GC/EI-MS and <sup>1</sup>H-NMR spectra as product 3 (data above). Note that products 6 and 7 in this scheme correspond to Compounds 33 and 34. Compound 33·HCl: mp = 260-270°C (dec), [α]<sub>D</sub><sup>26</sup> = +6.6 (c 1.0 in EtOH), [α]<sub>D</sub><sup>26</sup> = +0.4 (c 1.0 in EtOH). Compound 34·HCl: [α]<sub>D</sub><sup>23</sup> = -6.1 (c 1.0 in EtOH), [α]<sub>D</sub><sup>23</sup> = +0.1 (c 1.0 in EtOH). Compound 33·HI: The free base of Compound 33 was dissolved in EtOH and 47% hydriodic acid (1.1 equivt.) was added. The solvent was evaporated under vacuum and the resulting solid hydroiodide was recrystallized twice from heptane/EtOAc by slow evaporation: mp = 195-197°C. The absolute configuration of Compound 33·HI was determined to be R by single-crystal (monoclinic colorless needle, 0.50 x 0.05 x 0.03 mm) X-ray diffraction analysis using a Siemens R3m/V diffractometer (3887 observed reflections).

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Synthesis of Compound 22 was accomplished as described below. Compound 23 was synthesized in a similar manner.

Triethyl phosphonoacetate (17.2 g, 76.8 mmol) was slowly added to a suspension of sodium hydride (3.07 g, 76.8 mmol) in N,N-dimethylformamide (350 ml). After 15 minutes 3,3'-difluorobenzophenone (15.2 g, 69.8 mmol) was added to the solution and stirred an additional 18 hr. The reaction mixture was quenched with water and partitioned between water and ether. The combined organic layers were washed with brine and dried over anhydrous magnesium sulfate. The solvent was evaporated in vacuo to give 19.7 g of ethyl 3,3-bis(3-fluorophenyl)acrylate as a yellow oil.

To a solution of ethyl 3,3-bis(3-fluorophenyl)-acrylate (19.7 g, 68.4 mmol) in 200 ml of ethanol was added palladium hydroxide on carbon (3.5 g). The mixture was shaken under 60 psi of hydrogen for 3 hours,

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then filtered and evaporated *in vacuo* to give 19.5 g of product A as a colorless oil.

The ethyl ester A (19.2 g) was hydrolyzed by stirring for 6 days with 50 ml of 10 N sodium hydroxide.

5 The reaction mixture was then diluted with 50 ml of water and acidified to pH 0 with concentrated HCl. The aqueous mixture was extracted 3 times with ether and the ether extracts dried over magnesium sulfate and evaporated to give 3,3-bis(3-fluorophenyl)propionic acid  
10 as a white powder.

3,3-bis(3-fluorophenyl)propionic acid (13 g, 49.6 mmol) was dissolved in 50 ml (685 mmol) of thionyl chloride and stirred overnight at room temperature. The excess thionyl chloride was removed *in vacuo* on a rotary  
15 evaporator to give 13.7 g of product B as a yellow oil.

To acid chloride B (13.7 g, 49 mmol) dissolved in 100 ml of dry THF was added iron(III) acetylacetonate (0.52 g, 1.47 mmol). Methylmagnesium chloride (16.3 ml, 49 mmol) was then added over a period of 1 hr by syringe  
20 pump. The reaction was stirred for an additional hour, then quenched by pouring into ether/5% HCl. The ether layer was separated, washed with 5% HCl and saturated NaCl, and dried over sodium sulfate. The solvent was evaporated *in vacuo* to give  
25 4,4-bis(3-fluorophenyl)-2-butanone as a yellow oil. The crude oil was purified on silica gel using heptane/ethyl acetate as the elutant.

To 4,4-bis(3-fluorophenyl)-2-butanone (5.7 g, 21.9 mmol) in 25 ml of ethanol was added pyridine

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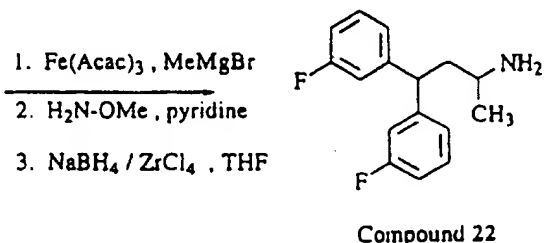
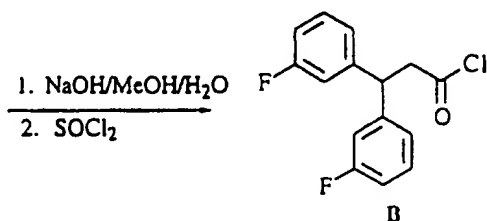
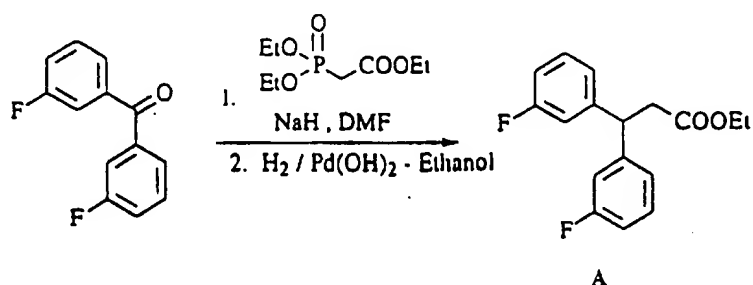
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(1.91 g, 24.1 mmol) and methoxylamine hydrochloride (2.01 g, 24.1 mmol). The reaction was stirred overnight at room temperature, then poured into ether/5% HCl. The ether layer was separated, washed with 5% HCl and  
5 saturated NaCl, and dried over sodium sulfate. The solvent was evaporated in vacuo to give 6.26 g of the O-methyl oxime of 4,4-bis(3-fluorophenyl)-2-butanone. To sodium borohydride (4.1 g, 108.3 mmol) in 15 ml of THF was slowly added zirconium tetrachloride (6.31 g,  
10 27.1 mmol). This mixture was stirred for 15 min, then the oxime (6.26 g, 21.7 mmol) in 6 ml of THF was added over 5 min. After 3 hours of stirring at room temperature, the reaction was worked up by slowly adding 50 mM sodium hydroxide followed by ether. The aqueous  
15 layer was extracted 4 times with ether, and the combined ether extracts were dried over sodium sulfate. The solvent was evaporated in vacuo to give 5.3 g of Compound 22.

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Synthesis of Compound 24 was accomplished as described below. Compounds 25-29, 52-53, 65, 76-78, 83, 90, 96-97, 115, and 135-136 were prepared in a similar manner.

- 5                   A suspension of magnesium turnings (0.95 g, 39.2 mmol) in 150 ml anhydrous diethyl ether was treated with 1-bromo-3-fluorobenzene (6.83 g, 39.2 mmol) dropwise via syringe. After 1.5 hr the solution was transferred via cannula to a flask containing
- 10                   o-anisaldehyde (5.0 g, 36.7 mmol) in 100 ml anhydrous diethyl ether at 0°C and stirred 2hr. The reaction mixture was quenched with water and partitioned between water and ether. The combined organic layers were

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washed with brine and dried over anhydrous magnesium sulfate to afford 7.90g (93% yield) of product A.

Pyridinium dichromate (16.0 g, 42.5 mmol) was added to a solution of the alcohol A (7.90 g, 34.0 mmol) in dichloromethane (100 ml), and the reaction was stirred 12 hr. Diethyl ether (300 ml) was added to the reaction mixture and the black solution was filtered through a silica gel plug (30 cm) and washed with an additional 500 ml ether. After evaporation of the solvent in vacuo, the solid was recrystallized from acetone to give 7.45 g (95% yield) of product B.

Diethyl cyanomethylphosphonate (7.0 g, 39.5 mmol) was slowly added to a suspension of sodium hydride (1.58 g, 39.5 mmol) in 100 ml N,N-dimethylformamide. After 30 minutes the ketone B was added to the solution and stirred an additional 2 hr. The reaction mixture was quenched with water, and partitioned between water and ether. The combined organic layers were washed with brine and dried over anhydrous magnesium sulfate. The solvent was evaporated in vacuo to give a pale yellow oil.

In a glass bomb, the oil was dissolved in 100 ml ethanol and 20 ml 10N NaOH. A catalytic amount of Raney Nickel suspended in water (ca. 15 mol percent) was added to the solution. The reaction mixture was shaken under 60 psi H<sub>2</sub> for 12 hr on a Parr Hydrogenator. After filtering off excess Raney Nickel, the solution was extracted with chloroform. The combined organic layers were washed with brine and dried over anhydrous



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magnesium sulfate. After filtration, the oil was run through a silica gel column in chloroform and methanol. The solvent was evaporated in vacuo to give a pale yellow oil. GC/EI-MS ( $R_t$ =8.10 min)  $m/z$  (rel. intensity)

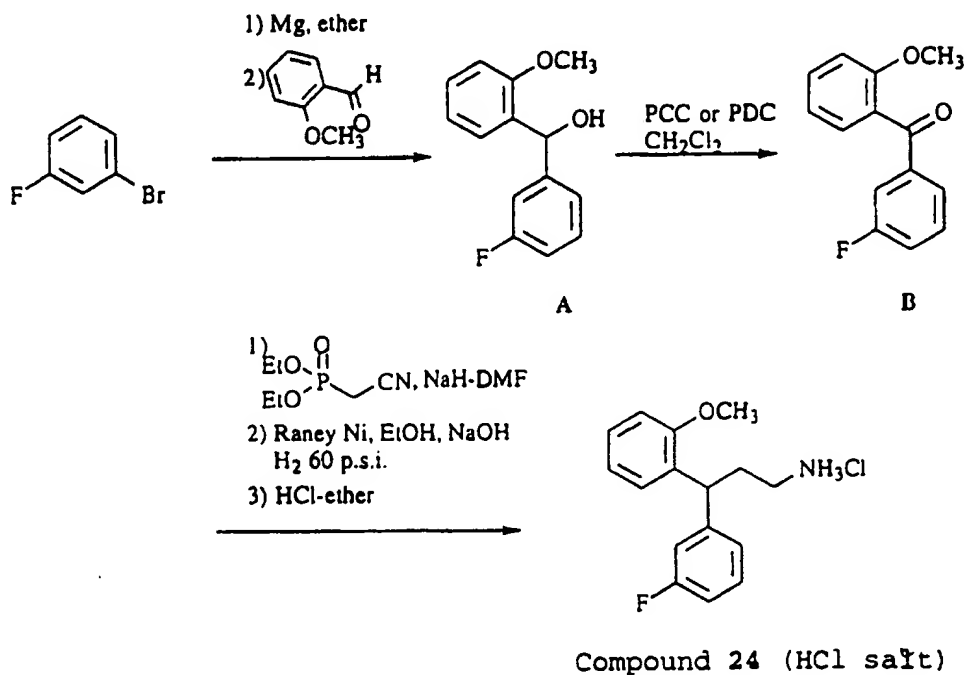
5 259 (100), 242 (44), 213 (48), 183 (42), 136 (50), 109 (94), 91 (60), 77 (25). The oil was then acidified with hydrogen chloride in diethyl ether. Evaporation of the ether afforded a pale yellow solid that was recrystallized in hot acetonitrile to afford 3.45 g

10 (42.1% yield) white needles of Compound 24, as the hydrochloride salt.

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Compounds 101 and 103 were synthesized from Compounds 25 and 24, respectively, by cleavage of their O-methyl ethers with borane tribromide in the normal manner.

Synthesis of Compound 30 was accomplished as described below. Compound 31 was prepared in a similar manner.

A suspension containing magnesium turnings (0.95 g, 39.1 mmol) in 150 ml anhydrous diethyl ether was treated with 1-bromo-3-fluorobenzene (6.85 g,

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39.1 mmol) dropwise via syringe. After 1.5 hr the solution was transferred via cannula to a flask containing 3-chlorobenzaldehyde (5.0 g, 35.6 mmol) in 100 ml anhydrous diethyl ether at 0°C and stirred 2 hr.

5 The reaction mixture was quenched with water and partitioned between water and ether. The combined organic layers were washed with brine and dried over anhydrous magnesium sulfate to afford 8.40 g (>99% yield) of product A.

10 Pyridinium chlorochromate (15.0 g, 39.8 mmol) was added to a solution of the alcohol A (8.40 g, 35.5 mmol) in 100 ml dichloromethane and stirred 18 hr. Diethyl ether (300 ml) was added to the reaction mixture and the black solution was filtered through a silica gel  
15 plug (30 cm), and washed with an additional 500 ml ether. After evaporation of the solvent the solid was recrystallized from acetone to give 6.31 g (76% yield) of product B.

Diethyl cyanomethylphosphonate (5.2 g, 29.6 mmol) was slowly added to a suspension of sodium  
20 hydride (1.2 g, 29.6 mmol) in N,N-dimethylformamide (100 ml). After 30 minutes the ketone B was added to the solution and stirred an additional 6 hr. The reaction mixture was quenched with water and partitioned  
25 between water and ether. The combined organic layers were washed with brine and dried over anhydrous magnesium sulfate. The solvent was evaporated in vacuo to give a yellow oil.

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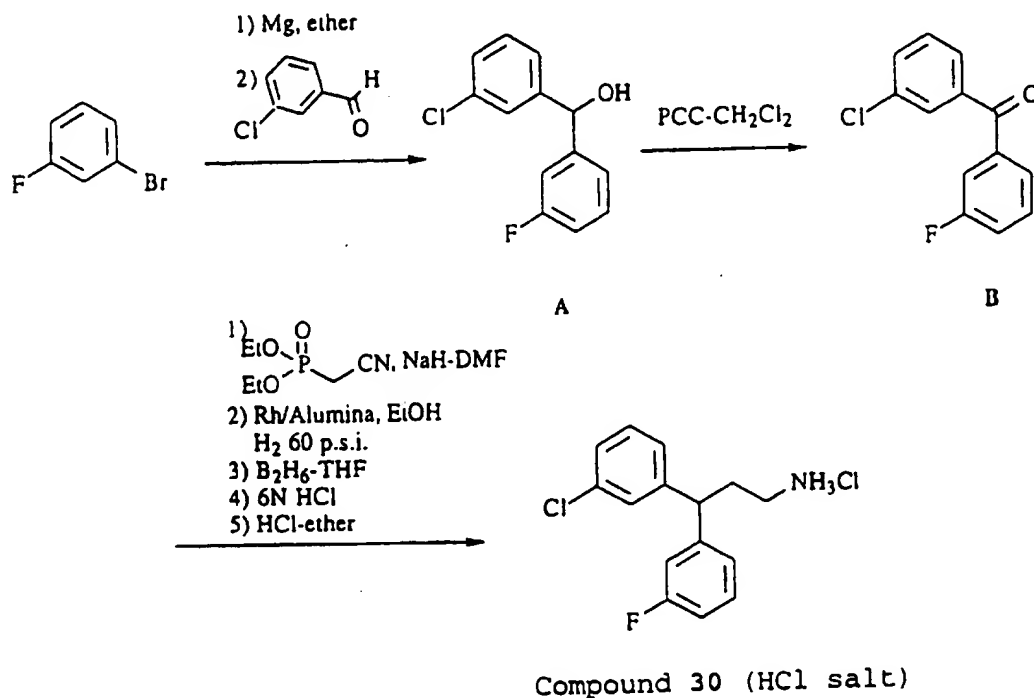
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In a glass bomb, the oil was dissolved in ethanol (100 ml) and 10N NaOH (20 ml). A catalytic amount of rhodium suspended on alumina (ca. 35 mol percent) was added to the solution. The reaction mixture was shaken under 60 psi H<sub>2</sub> for 24 hr on a Parr Hydrogenator. After filtering off excess catalyst, the solution was extracted with chloroform. The combined organic layers were washed with brine and dried over anhydrous magnesium sulfate. After filtration and evaporation of the solvent in vacuo, the oil was taken up in tetrahydrofuran (100 ml). Diborane (23.4 ml, 1.0 M) was added and the solution was refluxed for 1.5 hr. The solvent was evaporated in vacuo and 6N HCl (50 ml) was added carefully. The solution was refluxed for 1 hr. After cooling, the mixture was basified with 10N NaOH to pH 14 and partitioned between dichloromethane and water. The combined organic layers were dried over anhydrous magnesium sulfate and filtered. After evaporation of the solvent, the yellow oil was run through a silica gel column in chloroform and methanol. The solvent was evaporated in vacuo to give a yellow oil. GC/EI-MS (R<sub>t</sub>=8.15 min) m/z (rel. intensity) 263 (17), 246 (21), 211 (84), 196 (33), 183 (100), 165 (19), 133 (19). The oil was then acidified with hydrogen chloride in diethyl ether. Evaporation of the ether afforded 0.96 g of a white solid, Compound 30, as the hydrochloride salt.

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Synthesis of Compound 35 was accomplished as described below. Compounds 36-37 were prepared in a similar manner.

- 5 A solution of 3-fluorobenzaldehyde (3.0 g, 24.2 mmol) at 0°C in 150 ml diethyl ether was treated with 3.0 M ethyl magnesium chloride (12.7 ml, 25.4 mmol) in tetrahydrofuran (THF) via syringe. After 4 hr, the reaction mixture was quenched with water and partitioned
- 10 between water and ether. The combined organic layers

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were washed with brine and dried over anhydrous magnesium sulfate to afford 4.25 g of product A.

Pyridinium chlorochromate (6.53 g, 30.3 mmol) was added to a solution of A in dichloromethane (100 ml) and stirred 18 hr. Diethyl ether (300 ml) was added to the reaction mixture and the black solution was filtered through a silica gel plug (30 cm) and washed with an additional 500 ml ether. After evaporation of the solvent the solid was recrystallized from acetone to give 3.05 g of product B. The solvent was evaporated in vacuo to give a pale yellow oil.

Diethyl cyanomethylphosphonate (4.7 g, 26.4 mmol) was slowly added to a suspension of sodium hydride (1.1 g, 26.4 mmol) in 100 ml N,N-dimethylformamide. After 30 minutes the ketone B was added to the solution and stirred an additional 6 hr. The reaction mixture was quenched with water and partitioned between water and ether. The combined organic layers were washed with brine and dried over anhydrous magnesium sulfate. The solvent was evaporated in vacuo to give a yellow oil.

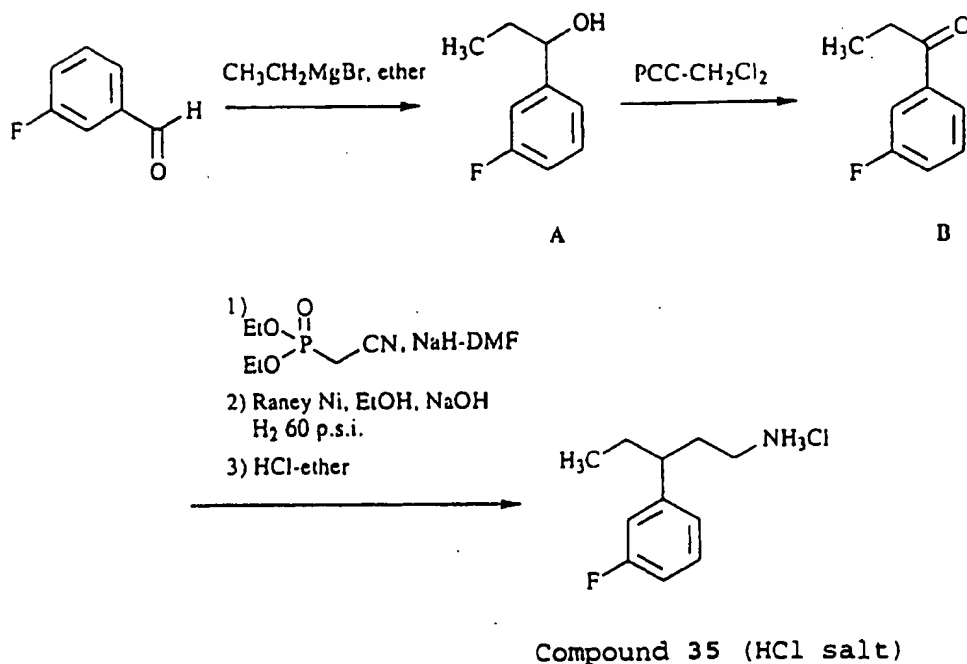
In a glass bomb, the oil was dissolved in 100 ml ethanol and 20 ml 10N NaOH. A catalytic amount of Raney Nickel suspended in water (ca. 15 mol percent) was added to the solution. The reaction mixture was shaken under 60 psi H<sub>2</sub> for 24 hr on a Parr Hydrogenator. After filtering off excess catalyst, the solution was extracted with chloroform. The combined organic layers were washed with brine and dried over anhydrous

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magnesium sulfate. After filtration, the oil was run through a silica gel column in chloroform and methanol. The solvent was evaporated in vacuo to give a pale yellow oil. GC/EI-MS ( $R_t=3.45$  min)  $m/z$  (rel. intensity) 5 167 (4), 150 (63), 135 (58), 109 (100), 96 (53), 75 (48). The oil was then acidified with hydrogen chloride in diethyl ether. Evaporation of the ether left a pale yellow solid that was recrystallized in hot acetonitrile to afford 2.2 g of Compound 35, as the 10 hydrochloride salt.



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Synthesis of Compound 38 was accomplished as described below.

To a solution of 3,3-bis(3-fluorophenyl)-  
-propionitrile (1.5 g, 6.17 mmol) in 250 ml of THF at  
5 -70°C was added butyl lithium (4.25 ml in hexanes, 6.8  
mmol) by syringe over 5 minutes. The solution was  
stirred for 5 min then methyl iodide (1.75 g, 12.3 mmol)  
was added over 1 min. The reaction mixture was then  
allowed to warm up to room temperature and worked up by  
10 diluting with ether and washing with 5% HCl and water.  
The ether layer was dried over sodium sulfate and  
evaporated to give 1.5 g of the methylated nitrile as a  
yellow oil.

To the 3,3-bis(3-fluorophenyl)-  
15 2-methyl-propionitrile (1.46 g, 5.7 mmol) in 50 ml of  
dichloromethane at 0°C was added diisobutylaluminum  
hydride (1.02 ml, 5.7 mmol) by syringe over a 10 min  
period. The reaction was stirred for 30 min at 0°C  
followed by 2 additional hours at room temperature. The  
20 reaction was worked up by adding 200 ml of 10% HCl and  
stirring at 40°C for 30 min followed by extraction of  
the product with dichloromethane. The organic layer was  
dried over sodium sulfate and evaporated to give 1.36 g  
of the product A.

25 To a solution of the aldehyde A (1.36 g,  
5.23 mmol) in 40 ml of ether at 0°C was added  
methylmagnesium bromide (5.23 ml in ether, 5.23 mmol).  
The reaction was stirred for 3 hr at room temperature,  
and then quenched with dilute HCl. The ether layer was



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separated, dried over sodium sulfate and evaporated to give 1.48 g of 4,4-bis(3-fluorophenyl)-3-methylbutan-2-ol.

To a solution of the alcohol (1.4 g, 5.07 mmol) in 300 ml of dichloromethane was added pyridinium chlorochromate (1.2 g, 5.58 mmol), and the mixture was stirred overnight. The reaction was then diluted with 100 ml of ether and filtered through a silica plug. The solvent was evaporated to give 1.39 g of product B.

The ketone B (1.3 g, 4.9 mmol) was added to a solution of methoxylamine hydrochloride (0.45 g, 5.38 mmol) and pyridine (0.44 ml, 5.38 mmol) in 30 ml of ethanol, and stirred overnight. The ethanol was then evaporated, and the residue taken up in ether and 10% HCl. The ether layer was separated, washed once with 10% HCl, dried over sodium sulfate and evaporated to give 1.4 g of the O-methyl oxime.

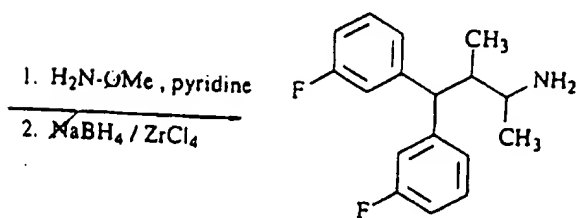
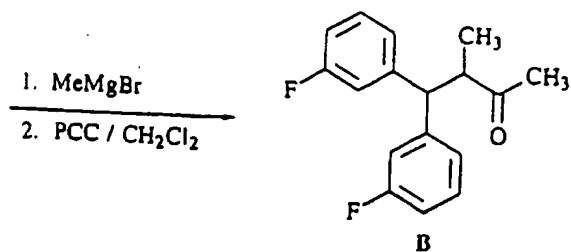
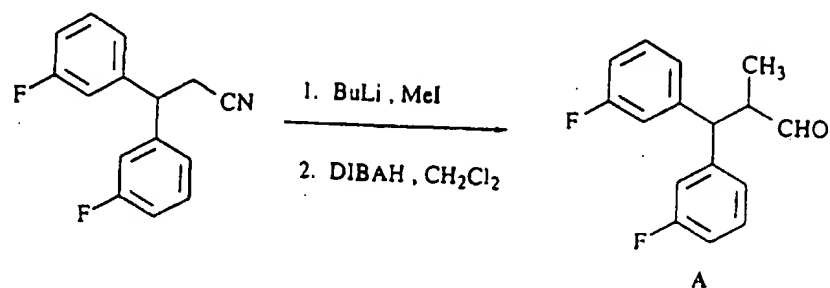
To a suspension of sodium borohydride (0.87 g, 23.1 mmol) in 5 ml of THF was added zirconium tetrachloride (1.35 g, 5.8 mmol), and the solution was stirred for 15 min followed by the addition of another 5 ml of THF. The O-methyl oxime (1.4 g, 4.6 mmol) in 5 ml of THF was then added, and the mixture stirred overnight. The THF was removed by evaporation in vacuo, and the residue treated with 10% sodium hydroxide. After the bubbling ceased ether was added and the layers separated. The aqueous layer was extracted four times with ether, and the combined ether extracts were dried

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over sodium sulfate. The ether was evaporated to give 1.25 g of Compound 38.



Compound 38

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Compound 32 and Compounds 39 - 53 were synthesized according to standard procedures as described above.

Compounds 107, 116, 139, and 143 were prepared  
5 as synthetic intermediates used in the preparation of Compounds 32, 115, 20, and 25, respectively.

Compound 50 was also prepared using the chiral synthesis described below.

To an ice-cold solution of  
10 *N*-benzyl-(*S*)- $\alpha$ -methylbenzylamine (18.0 g, 85.2 mmol) in THF (75 ml) was added butyl lithium (2.5 M in hexane; 37.5 ml, 93.8 mmol) via a syringe over a period of 10 min at such a rate as to keep the reaction temperature below 10°C during the addition. The  
15 reaction was then stirred at 0°C for 15 min. The reaction was cooled to -78°C in a dry ice/isopropanol bath and then a solution of benzyl crotonate (15.0 g, 85.2 mmol) in THF (100 ml) was added dropwise over a period of 45 min. The reaction was stirred at -78°C for  
20 15 min, and then saturated NH<sub>4</sub>Cl (50 ml) was added. The reaction mixture was then quickly transferred to a separatory funnel containing saturated NaCl (500 ml) and ether (200 ml). The layers were separated and the aqueous layer extracted with ether (200 ml). The  
25 combined organic layers were dried, evaporated, and chromatographed on silica gel (50 mm x 30 cm) (hexane-ethyl acetate [20:1]) to yield 21.0 g, 63.7% of product A. <sup>1</sup>H-NMR showed that the diastereoselectivity of the reaction is > 90%.

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A mixture of magnesium (2.58 g, 106 mmol), THF (200 ml), and 1-bromo-3-fluorobenzene (18.60 g, 106.3 mmol) was refluxed for 45 min. While still under reflux, product A (16.45 g, 42.45 mmol) was added via syringe with THF (25 ml) over a 2 min period. The reaction was refluxed for 1 hr, and then allowed to cool to room temperature. Saturated  $\text{NH}_4\text{Cl}$ (aq., 200 ml) was added. The reaction mixture was then transferred to a separatory funnel containing saturated  $\text{NaCl}$ (aq) (500 ml) and diethyl ether (200 ml). The layers were separated and the aqueous layer extracted with ether (200 ml). The combined organic layers were dried over sodium sulfate and evaporated to give 21.41 g of product B as a yellow liquid.

Product B (20.02 g, 42.45 mmol, theoretical) was dissolved in acetic acid (120 ml) and sulfuric acid (30 ml). The reaction was stirred at 90°C for 1 hr. The acetic acid was rotary evaporated giving a brown sludge. This material was placed in an ice bath and cold water (400 ml) was added. The product immediately precipitated. To the reaction was slowly added 10 N  $\text{NaOH}$  (150 ml) to neutral pH. Diethyl ether (200 ml) was added to this mixture. The mixture was shaken until there was no undissolved material. The ether layer was separated, washed with water (2 x 100 ml), dried over sodium sulfate, and rotary evaporated yielding 13.14 g (68.2% based on ester) of a thick brown oil. This oil was taken up in ether and converted to the hydrochloride

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salt with hydrogen chloride in diethyl ether to give product C as a yellow-white solid.

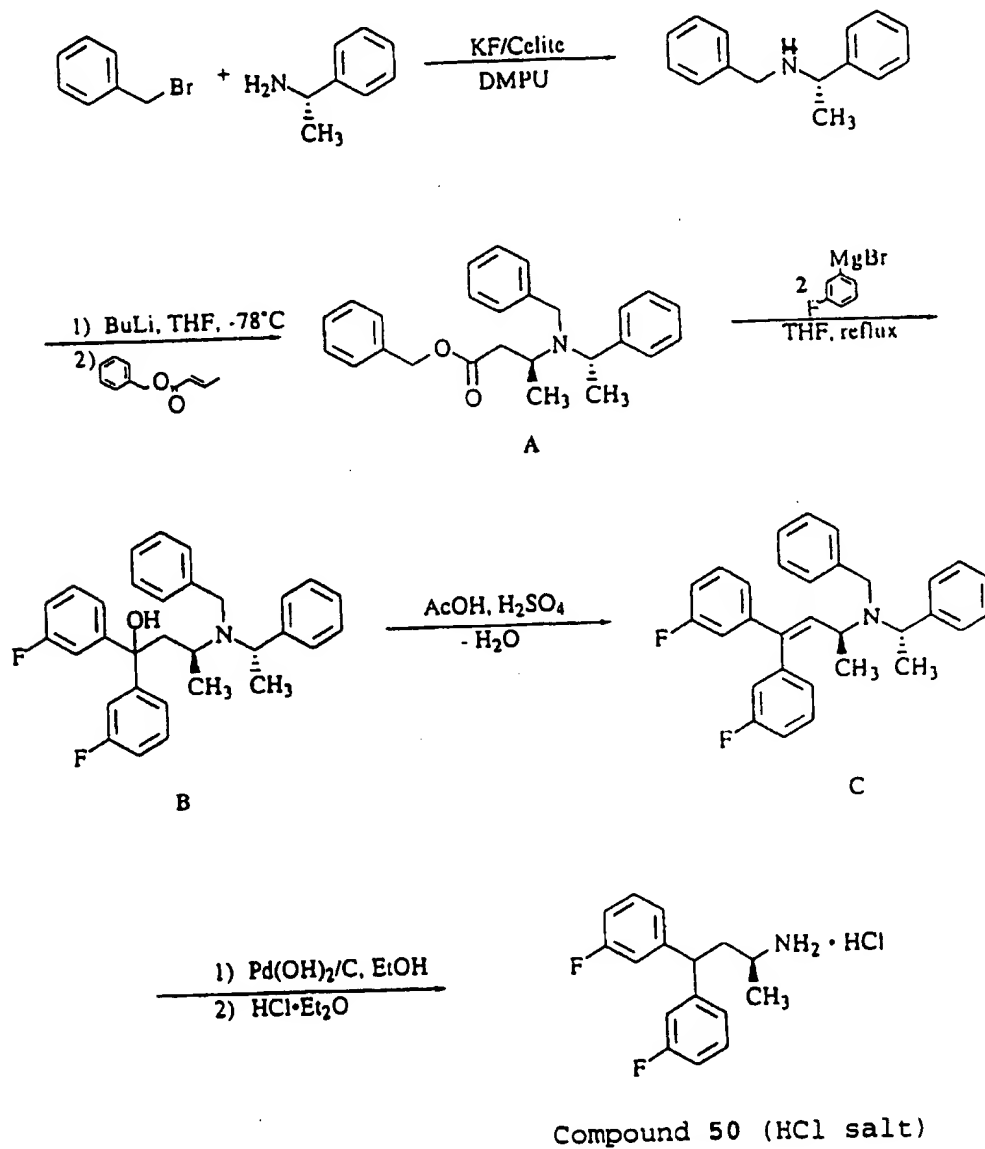
Product C (7.17 g, 14.6 mmol) was taken up in absolute ethanol (200 ml). Pearlman's catalyst  
5 (Pd(OH)<sub>2</sub>/C; 2.00 g) was added. The reaction was shaken under 70 psi hydrogen gas at 70°C for 20 hr, and the reaction mixture was filtered through Celite. The filtrate was rotary evaporated to give 3.54 g of a light yellow glass. This material was taken up in diethyl  
10 ether (100 ml) and was basified with 1 N NaOH (25 ml). The ether layer was washed with water (1 x 25 ml), dried over sodium sulfate, and rotary evaporated to give 2.45 g of a light yellow oil. This material was Kugelrohr distilled (90-100°C, 1 mm Hg) to give 1.17 g  
15 of a colorless liquid. This material was taken up in diethyl ether and converted to the hydrochloride salt with ethereal hydrogen chloride. After rotary evaporation, the salt was recrystallized from 0.12 N HCl (200 mg/ml). The crystals were filtered off and were  
20 washed with cold 0.12 N HCl yielding 0.77 g (18%) of Compound 50 as silvery white crystals (as the hydrochloride salt).

Compound 51 was synthesized in a similar manner to Compound 50 utilizing *N*-benzyl-*(R)*- $\alpha$ -  
25 methylbenzylamine as a chiral starting material.

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Synthesis of Compound 54 was accomplished as described below.

To a solution of 3,3'-difluorobenzophenone (5 g, 22.9 mmol) and methyl cyanoacetate (3.4 g, 34.4 mmol) in 15 ml of ether was added titanium isopropoxide (16.9 ml, 57.25 mmol). This solution was stirred for 6 days at room temperature then quenched with 0.5 mol of HCl in 300 ml of water. The mixture was diluted with 100 ml of ether, and the layers separated. The ether layer was washed with 5% HCl and saturated brine, then dried over sodium sulfate. The solvents were evaporated in vacuo to give 8 g of product A.

Compound A was dissolved in 50 ml of isopropanol, followed by the addition of a small amount of bromocresol green. Sodium cyanoborohydride (1.52 g, 24.2 mmol) was added all at once followed immediately with the dropwise addition of concentrated HCl, added at such a rate as to keep the solution yellow. After 2 hours the reaction was worked up by partitioning between ether and water. The ether layer was washed with water and saturated brine, dried over sodium sulfate, and concentrated to give the product B.

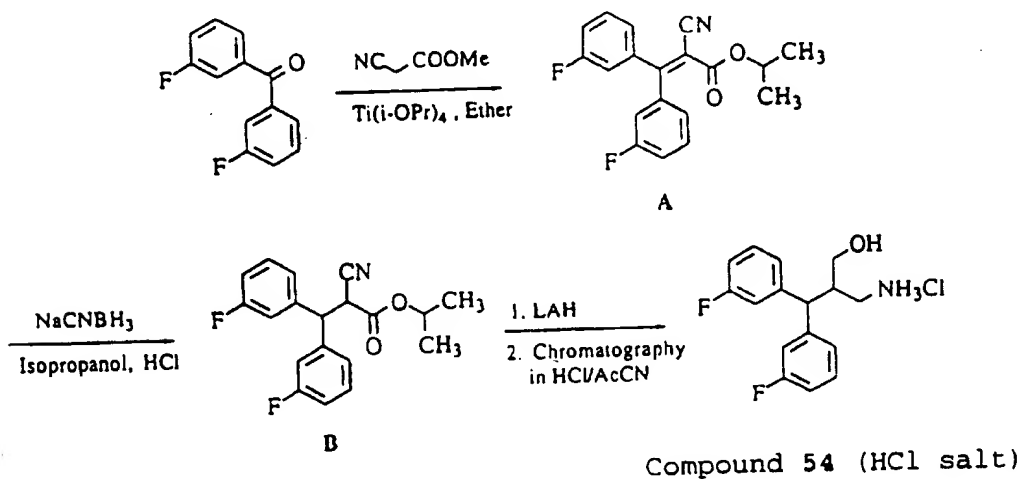
To a solution of lithium aluminum hydride (30.4 ml, 30.4 mmol) in THF was added product B (1 g, 3.04 mmol) in 2 ml of THF over a period of 30 seconds. This solution was stirred overnight at room temperature, then quenched with the addition of 20 ml of ethyl acetate. The solvents were then removed in vacuo, and the resulting oil was dissolved in aqueous HCl and

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acetonitrile. The product was then purified on a C-18 column with a gradient of 0.1% HCl to acetonitrile to give 82 mg of Compound 54, as the hydrochloride salt. EI-MS  $m/z$  (relative intensity) 277 ( $M^+$ , 100), 260 (2.4), 242 (8.6), 229 (28), 215 (11.7), 204 (16), 183 (12), 133 (9.5), 124 (14), 109 (6.8), 30 (22).



Compound 55 was synthesized analogously to Compound 21 except that ethyl iodide was used in the alkylation step. GC/EI-MS ( $R_t$  = 7.43 min)  $m/z$  (relative intensity) 275 ( $M^+$ , 100), 258 (66), 229 (63), 204 (57), 201 (72), 183 (84), 134 (57), 124 (68), 109 (98), 72 (72).

The synthesis of Compound 56 was accomplished as follows.

The alcohol A was synthesized from 3-fluorobromobenzene and 3-fluoro-2-methylbenzaldehyde



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as described for product A in the synthesis of Compound 24.

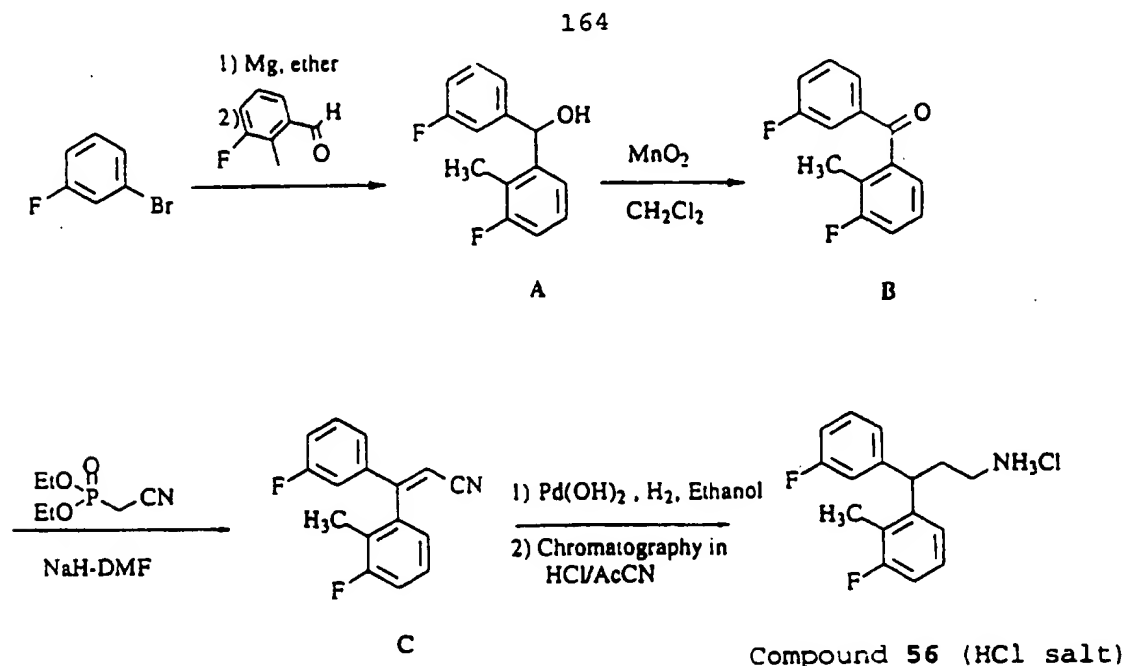
The alcohol A (8.4 g, 36.2 mmol) was stirred with manganese dioxide (12.6 g, 144.8 mmol) in 100 ml of  
5 dichloromethane for 4 days. The reaction mixture was then diluted with ether and filtered through a 0.2 micron teflon membrane filter. The filtrate was concentrated to give 7.6 g of the ketone B.

The substituted acrylonitrile C was  
10 synthesized as described for product A in the Compound 20 synthesis.

To the nitrile C (4 g, 15.7 mmol) in 240 ml of ethanol was added 2 g of 10% palladium dihydroxide on carbon. This mixture was hydrogenated at 60-40 psi for  
15 3 days. The reaction mixture was then filtered and concentrated. The resulting oil was dissolved in chloroform and chromatographed on silica gel (30% methanol/5% isopropylamine in chloroform) to give the amine. This amine was dissolved in aqueous  
20 HCl/acetonitrile and purified via HPLC on C-18 (10% acetonitrile/0.1% HCl to 50% acetonitrile/0.1% HCl over 60 min) then lyophilized to give 800 mg of Compound 56, as the hydrochloride salt. GC/EI-MS ( $R_t$  = 7.39 min)  $m/z$  (relative intensity) 261 ( $M^+$ , 64), 244 (56), 229 (57),  
25 215 (100), 203 (53), 183 (21), 133 (39), 122 (31), 109 (32).

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The synthesis of Compound 57 was accomplished as follows.

To a solution of 5-fluoro-2-methylbenzonitrile (5 g, 37 mmol) in 50 ml of THF was added

5 3-fluorophenylmagnesium bromide (46 ml, 40 mmol) and copper (I) cyanide (0.072 g, 0.8 mmol). This solution was refluxed for 4 hours, then poured into ether/20% HCl and stirred for a further 2 hours. The layers were separated, and the ether layer washed with water and

10 saturated brine. The solution was dried over sodium sulfate and concentrated. The crude oil was purified on silica (hexane to 50% dichloromethane in hexane over 60 min) to give 6.7 g of the ketone A.

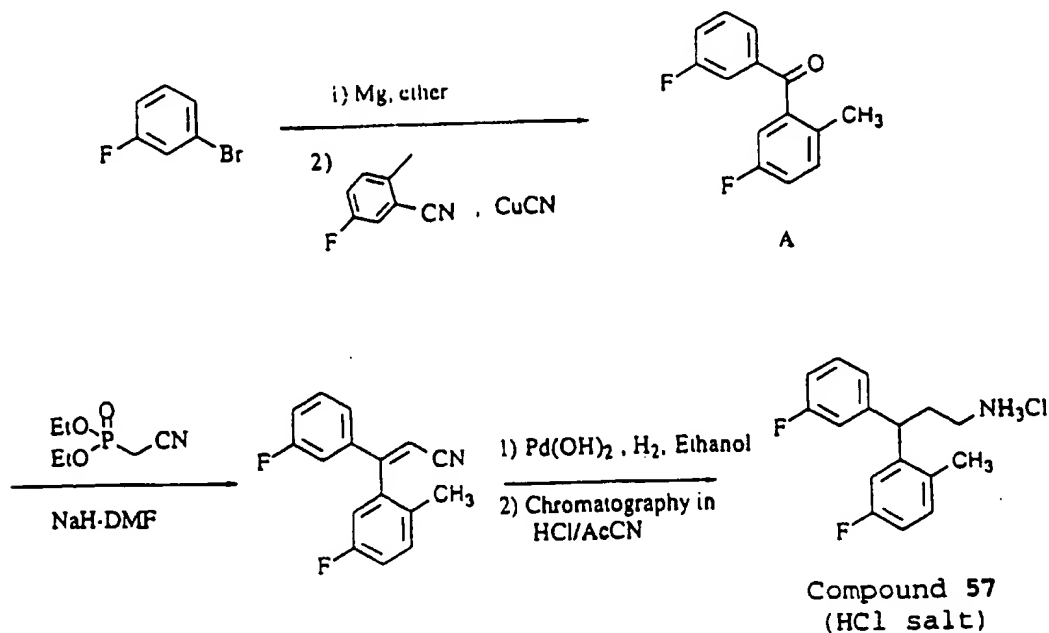
The ketone A was converted to Compound 57 as

15 described for Compound 56. GC/EI-MS ( $R_t$  = 7.35 min)  $m/z$  (relative intensity) 261 ( $M^+$ , 52), 244 (41), 229 (67), 215 (100), 203 (42), 201 (42), 183 (21), 133 (45), 122 (28), 109 (26).

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The synthesis of Compound 58 was accomplished as follows.

To a solution of 5-fluoro-2-methylbenzoyl chloride (2.24 g, 13 mmol) in 10 ml of dry THF was added iron III acetylacetonate (0.16 g, 0.44 mmol). The solution was cooled to 0°C, and a THF solution of 5-fluoro-2-methylphenylmagnesium bromide (20 ml, 15.5 mmol) was added by syringe over a period of 30 min. The reaction was stirred for another 30 min, then poured slowly into ether/5% HCl. The ether layer was separated, washed with saturated brine, dried over sodium sulfate, and concentrated to give 3.2 g of ketone A.

Dry THF (30 ml) was cooled to -78°C followed by the addition of butyl lithium (5.85 ml, 14.6 mmol, 2.5 M solution in hexanes). Acetonitrile (0.76 ml, 14.62 mmol) was then added over a period of 2 min, then allowed to stir at -78°C for 15 min. To this solution

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was added ketone A (3 g, 12.2 mmol) in 5 ml of THF. The solution was stirred for 30 min at -78°C then allowed to warm to room temperature and stirred overnight. The reaction mixture was partitioned between ether and 5% HCl. The ether layer was separated, washed with saturated brine, dried over sodium sulfate, and concentrated to give 2.2 g of the nitrile B.

The nitrile B (1 g, 3.48 mmol) was dissolved in 30 ml of ethanol and 3 ml of 10 N sodium hydroxide. To this solution was added 1 g of a 50% aqueous slurry of Raney nickel, and the mixture was hydrogenated at 60 psi for 20 hours. The reaction was filtered and concentrated to a white solid. This residue was taken up in ether/water and the ether layer separated. The ether solution was dried over sodium sulfate and concentrated to give 0.96 g of the hydroxyamine C.

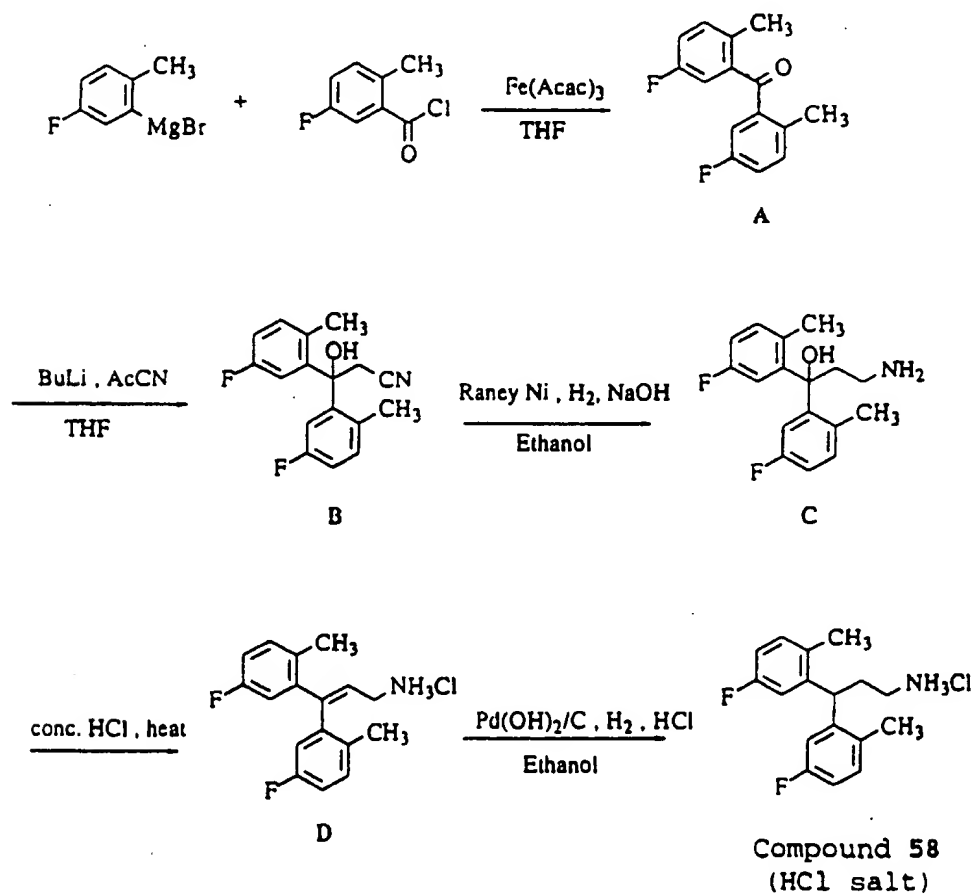
The hydroxyamine C (0.96 g, 3.3 mmol) was taken up in concentrated HCl and heated to 70°C which caused brief solution, and then precipitation of the alkene D. The alkene was collected by filtration and dissolved in 30 ml of ethanol and 1 ml of conc. HCl. Palladium dihydroxide on carbon (0.4 g) was added to the solution, and the mixture hydrogenated at 60 psi for 24 hours. The product was isolated by filtering off the catalyst and evaporating the solvent. The residue was dissolved in 0.1% HCl and acetonitrile, and purified on C-18 (15% acetonitrile/0.1% HCl to acetonitrile) to give 0.6 g of Compound 58, as the hydrochloride salt. GC/EI-MS ( $R_t$  = 7.82 min)  $m/z$  (relative intensity) 275

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(M<sup>+</sup>, 100), 258 (20), 243 (74), 229 (38), 214 (65), 201 (31), 196 (32), 183 (20), 148 (35), 138 (42), 133 (48), 122 (69), 109 (41).



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Synthesis of Compound 59 was accomplished as follows.

Compound 20 (2.0 g, 7.05 mmol) was dissolved in abs. EtOH (200 ml) and cooled to 5-10°C in an ice bath. Acetaldehyde (0.395 ml, 7.05 mmol, cooled to -4°C) was added followed by nickel-aluminum alloy (200 mg, Fluka Chemika), and the reaction was hydrogenated on a Parr apparatus at 50 psi for 2 hr. GC/MS showed 75% yield of the product and 2% of the *N,N*-diethyl side-reaction product. The reaction mixture was filtered through diatomaceous earth and the filtrate was evaporated under reduced pressure. The crude product was dissolved in isopropanol (5 ml)/ether (60 ml)/ethereal HCl (1 M), and then hexane (5 ml) was added to the cloud point. The cloudy mixture was filtered through paper, then hexane (10 ml) was added to the cloud point, and the solution was filtered again. The filtrate was stoppered and the product was allowed to crystallize at room temperature. The crystals were collected and dried to provide 0.325 g (14.8% yield) of Compound 59, as the hydrochloride salt (colorless needles).

The synthesis of Compound 60 was accomplished as follows. Compounds 66, 69, 108, 123, 142, and 145 can be synthesized in a similar manner starting from Compounds 33, 50, 32, 60, 25 and 119, respectively.

Compound 20 (as the free base) (1.0 g, 4.0 mmol) was refluxed in ethyl formate (150 ml) for 2 hr. The solvent was then removed under reduced

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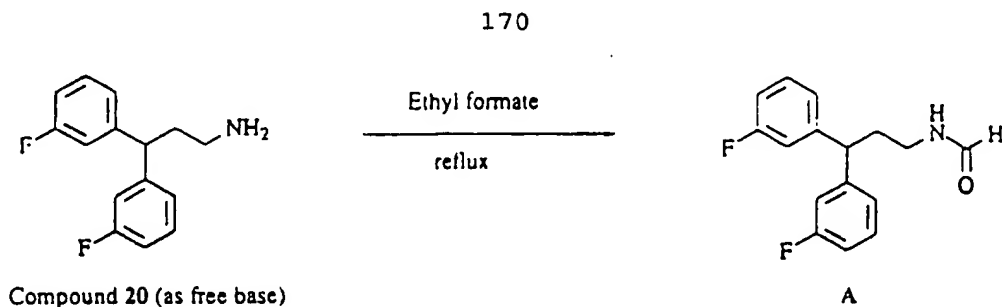
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pressure to provide 1.1 g, 99% yield of formamide A as a colorless oil. GC/MS showed the product to be 100.0% pure and was used in the following step without further purification.

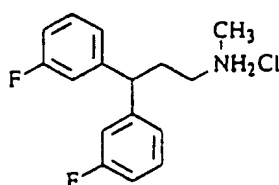
5                   The formamide A (1.1 g, 4.0 mmol) was dissolved in dry THF (100 ml) and heated to reflux (no condenser). Borane-methyl sulfide complex (1.2 ml, 12 mmol, 10.5 M) was added dropwise over a period of 3 min to the refluxing solution. Reflux was maintained for  
10                   approximately 15 min, open to the air, until the reaction volume was reduced to approximately 30 ml. The reaction was then cooled in an ice bath, and ice (5 g, small pieces) was carefully added followed by H<sub>2</sub>O (25 ml) and conc. HCl (25 ml). The acidic solution was refluxed  
15                   for 30 min. The reaction mixture was then cooled in an ice bath, basified with NaOH (10N), extracted with ether (3 X 100 ml), dried (Na<sub>2</sub>SO<sub>4</sub>, anhydrous), and evaporated under reduced pressure. The crude product was dissolved in ether (10 ml)/hexane (50 ml) and ethereal HCl (1 M)  
20                   was added dropwise to precipitate the hydrochloride salt. The salt was collected and recrystallized from isopropanol (3 ml)/ether (40 ml) to provide 0.5 g of Compound-60, as the hydrochloride salt.

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1) Borane-methyl sulfide, THF  
2) HCl



Compound 60 (HCl salt)

Alternatively, Compound 60 was synthesized from commercially available starting materials in the following four step reaction sequence. The first intermediate in this synthetic route,

5 ethyl-*N*-benzyl-*N*-methyl-3-aminopropionate, was prepared by conjugate addition of *N*-benzylmethylamine to ethyl acrylate. The ester functionality of the first intermediate was then reacted with two equivalents of Grignard reagent (prepared from 1-bromo-3-fluorobenzene)

10 to provide *N*-benzyl-*N*-methyl-3-hydroxy-3-(bis-3-fluorophenyl) propylamine. The Grignard reaction product was then dehydrated in a mixture of 6*N* HCl/acetic acid to yield

*N*-benzyl-*N*-methyl-3-(bis-3-fluorophenyl)-2-propenamine.

15 Catalytic hydrogenation of this material as its hydrochloride salt in ethanol over Pearlman's catalyst [Pd(OH)<sub>2</sub>/C] provided, after recrystallization from ethyl



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acetate, colorless, needles of Compound 60 as the hydrochloride salt.

In a 500-mL, 3-necked flask equipped with thermometer, reflux condenser, and a 125-mL addition  
5 funnel [charged with ethyl acrylate (88.3 mL, 81.5 g, 0.815 mol)] was placed *N*-benzylmethylamine (100 mL, 94.0 g, 0.776 mol). The ethyl acrylate was added dropwise to the stirring reaction mixture over a period of 30 min. After stirring for 18 h at room temperature,  
10 the product was vacuum distilled and the fraction containing product was collected at 78-95°C (0.12-0.25 mm Hg), (138 g, 80% yield): Bp 78-95°C (0.12-0.25 mm Hg); TLC,  $R_f$  = 0.23 [hexane-EtOAc (5:1)],  $R_f$  = 0.57 [MeOH-CHCl<sub>3</sub> (100:5)]; GC,  $t_r$  = 6.06 min; MS, 221 (M<sup>+</sup>), 206 (M-CH<sub>3</sub>), 192 (M-C<sub>2</sub>H<sub>5</sub>), 176 (M-OC<sub>2</sub>H<sub>5</sub>),  
15 144 (M-C<sub>6</sub>H<sub>5</sub>), 134 [CH<sub>2</sub>N(CH<sub>3</sub>)CH<sub>2</sub>Ph], 120 [N(CH<sub>3</sub>)CH<sub>2</sub>Ph], 91 (C<sub>7</sub>H<sub>7</sub>), 77 (C<sub>6</sub>H<sub>5</sub>), 42 (CH<sub>2</sub>CH<sub>2</sub>N); <sup>1</sup>H NMR (free base, CDCl<sub>3</sub>) δ 1.25 ppm (t,  $J$  = 7.1, 3H, CH<sub>2</sub>CH<sub>3</sub>), 2.20 (s, 3H, NCH<sub>3</sub>), 2.51 (t,  $J$  = 7.3, 2H, COCH<sub>2</sub>), 2.74 (t,  $J$  = 7.2, 2H, CH<sub>2</sub>N), 3.51 (s, 2H, NCH<sub>2</sub>Ph), 4.13 (q,  $J$  = 7.1, 2H, OCH<sub>2</sub>CH<sub>3</sub>), 7.18-7.35 (m, 5H, ArH); <sup>13</sup>C NMR (free base, CDCl<sub>3</sub>) δ 15.2 (CH<sub>2</sub>CH<sub>3</sub>), 34.0 (COCH<sub>2</sub>), 42.9 (NCH<sub>3</sub>), 53.8 (NCH<sub>2</sub>), 61.4 (OCH<sub>2</sub>CH<sub>3</sub>), 63.1 (CH<sub>2</sub>Ph), 128.0 (CH), 129.2 (CH), 130.0 (CH), 139.9 (q), 173.7 (q).

25 In a 5-L, four-necked, round-bottom flask, under nitrogen, were placed Mg [51.5 g, 2.12 mol, turnings, washed with THF (2 x 300 mL)] and THF (2 L). An addition funnel was charged with 1-bromo-3-fluorobenzene (neat, 392.8 g, 2.24 mol).

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One-twentieth of the bromide was added to the magnesium suspension followed by one crystal of iodine. After initiation of the Grignard reaction the remaining 1-bromo-3-fluorobenzene was then added to the refluxing mixture over a period of 50 min. The reaction was refluxed for an additional 45 min. To the refluxing solution of Grignard reagent was added a solution of ethyl *N*-benzyl-*N*-methyl-3-aminopropionate (187.5 g, 0.847 mol) in THF (100 mL) over a period of 20 min. After the ester addition was complete, the reaction was refluxed for 1h. The reaction was then cooled in an ice bath. Saturated  $\text{NH}_4\text{Cl}$  (aq., 400 mL) and  $\text{H}_2\text{O}$  (400 mL) were added and the mixture was transferred to a separatory funnel. The organic layer was separated and the aqueous layer was extracted once with THF (400 mL). The combined organic layers were washed with satd.  $\text{NaCl}$ , (2 x 200 mL, aq.), dried (anh.  $\text{Na}_2\text{SO}_4$ ), filtered through paper, and rotary evaporated vacuum to yield 281.6 g (90%) of crude product as an orange, viscous oil. This material (281.6 g, 0.766 mol) was dissolved in acetonitrile (1.4 L). Concentrated hydrochloric acid (65.0 mL, 0.786 mol, 12N) was added to the stirring filtrate. The crystallizing mixture was then cooled to -20 °C for 17 h. The product was collected, washed with cold acetonitrile (800 mL), and dried to provide a white solid, 235.6 g (69% yield from the ester). For analytical purposes, the hydrochloride salt was further purified by recrystallization from acetonitrile: mp 194-197°C (uncorr.); TLC,  $R_f$  = 0.23 [hexane-EtOAc

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(5:1)],  $R_f = 0.85$  [MeOH-CHCl<sub>3</sub> (100:5)],  $R_f = 0.72$  [MeOH-CHCl<sub>3</sub> (100:3)]; GC,  $t_R = 10.93$  min; MS, 367 (M<sup>+</sup>), 272 (M-C<sub>5</sub>H<sub>4</sub>F), 258 (M-CH<sub>2</sub>Ph-H<sub>2</sub>O), 219 [(C<sub>6</sub>H<sub>4</sub>F)<sub>2</sub>CH], 148 [CH<sub>2</sub>CH<sub>2</sub>N(CH<sub>3</sub>)CH<sub>2</sub>Ph], 134 [CH<sub>2</sub>N(CH<sub>3</sub>)CH<sub>2</sub>Ph], 91 (C<sub>7</sub>H<sub>7</sub>), 42 (CH<sub>2</sub>CH<sub>2</sub>N); <sup>1</sup>H NMR (free base, CDCl<sub>3</sub>) δ 2.18 (s, 3H, NCH<sub>3</sub>), 2.41 (m, 2H, CHCH<sub>2</sub>), 2.58 (m, 2H, CH<sub>2</sub>N), 3.42 (s, 2H, CH<sub>2</sub>Ph), 6.86 (dt,  $J_1 = 8.5$ ,  $J_2 = 1.8$ , 2H, Ar-H), 7.18-7.30 (m, 10H, Ar-H), 8.33 (bs, 1H, OH); <sup>13</sup>C NMR (free base, CDCl<sub>3</sub>) δ 35.6 (CHCH<sub>2</sub>), 41.5 (CH<sub>3</sub>, NCH<sub>3</sub>), 54.3 (CH<sub>2</sub>, CH<sub>2</sub>N), 62.6 (CH<sub>2</sub>, CH<sub>2</sub>Ph), 113.1 (d,  $J = 23$ , CH, Ar-C<sub>5,5</sub>), 113.5 (d,  $J = 23$ , CH), 121.2 (d,  $J = 3$ , CH), 127.5 (CH), 128.5 (CH), 129.2 (CH), 129.5 (CH), 129.6 (CH), 137.0 (q), 150.2 (q), 162.8 (d,  $J = 243$ , q, Ar-C<sub>3,3</sub>).

In a 5-L, 3-necked reaction vessel, equipped with an overhead mechanical stirrer, reflux condenser, and thermometer, was placed *N*-benzyl-*N*-methyl-3-hydroxy-3-bis(3-fluorophenyl)propylamine hydrochloride (225.4 g, 0.559 mol), 6*N* HCl (1392 mL) and glacial HOAc (464 mL). The suspension was heated in a water bath (80-85 °C) and stirred for 18 h. After 18 h of heating, the reaction mixture was cooled in an ice/MeOH bath. Ethyl acetate (500 mL) was added to the cooled reaction mixture. NaOH (10*N*, 1.7 L) was then added to the cooled mixture over a period of 25 min at such a rate as to keep the temperature below 40 °C. The mixture was transferred to a 6-L separatory funnel. The organic layer was separated and the aqueous layer was extracted with ethyl

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acetate (2 x 500 mL). The combined organic layers were washed with satd. NaCl (2 x 100 mL, aq.), dried Na<sub>2</sub>SO<sub>4</sub> (250 g), rotary evaporated, and then dried under vacuum to provide 185.6 g (95% yield) of the free base as a fluid, brownish-colored oil.

The material above was stirred with hexane (1.5 L). The resulting solution was filtered through paper. 4M HCl in dioxane (146 mL) was added dropwise with stirring to the filtrate over a period of 5 min. The semi-translucent solvent was then decanted away from the light-yellow colored, semisolid precipitate. The crude hydrochloride salt was dissolved in refluxing ethyl acetate (600 mL) and was filtered. The filtrate was then thoroughly cooled in an ice bath, and hexane (110 mL) was slowly added, with vigorous stirring. After cooling in an ice bath for 2 h, the entire flask filled with a white crystalline solid. This material was collected on a filter funnel, washed with ice-cold hexane/ethyl acetate [(1:4), 400 mL], and dried to yield 128.7 g, 59.7% of a white solid. On standing the mother liquor precipitated another 14.8 g of an off-white solid. Total yield 128.7 g + 14.8 g = 143.5 (67%). Mp 141-142 °C (uncorr.); TLC, R<sub>f</sub> = 0.20 [hexane-EtOAc (5:1)], R<sub>f</sub> = 0.75 [MeOH-CHCl<sub>3</sub> (100:5)], R<sub>f</sub> = 0.49 [MeOH-CHCl<sub>3</sub> (100:3)]; GC; t<sub>R</sub> = 10.40 min; MS, 349 (M<sup>+</sup>), 330, 301, 281, 258 (M-CH<sub>2</sub>Ph), 240, 229 [M-N(CH<sub>3</sub>)CH<sub>2</sub>Ph], 201, 183, 146, 133, 109, 91 (CH<sub>2</sub>C<sub>6</sub>H<sub>5</sub>), 65, 42 (CH<sub>2</sub>NHCH<sub>3</sub>); <sup>1</sup>H NMR (free base, CDCl<sub>3</sub>) δ 2.20 ppm (s, 3H, NCH<sub>3</sub>), 3.08 (d, J = 6.8, 2H, CH<sub>2</sub>N), 3.47 (d, J < 1, 2H, CH<sub>2</sub>Ph),

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6.29 (t,  $J = 6.8$ , 1H, CH), 6.85-7.04 (m, 6H, ArH),  
7.19-7.35 (m, 7H, ArH).

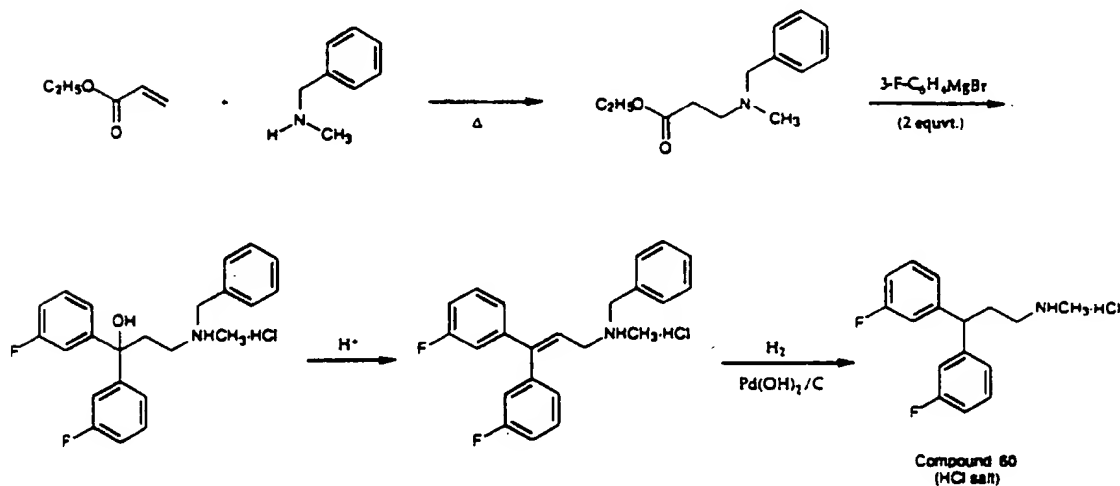
*N*-Benzyl-*N*-methyl-3-bis(3-fluorophenyl)allylamine  
5 hydrochloride (120.0 g, 0.311 mol) was dissolved in abs.  
EtOH (1250 mL). Pd(OH)<sub>2</sub>/charcoal (10.0 g, ~20% Pd, Fluka  
Chemical) was added. The reaction mixture was stirred  
under a steady flow of hydrogen gas for 18 h at 25 °C  
(atmospheric pressure). The mixture was then filtered  
10 through Celite<sup>®</sup>/fritted glass, the catalyst was washed  
with EtOH (2 x 50 mL), and the solvent was removed under  
reduced pressure to yield 95.4 g, 103% of crude product.  
This material was dissolved in refluxing ethyl acetate  
(300 mL) with vigorous stirring and filtered. The flask  
15 was allowed to stand for 2 h at 25 °C, during which time  
the hydrochloride salt began to crystallize as needles.  
The flask was then cooled, the product was collected,  
washed with ice-cold ethyl acetate (20 mL), and dried to  
yield 73.7 g, 80%, of Compound 60 as a white,  
20 crystalline solid. Mp 129-130°C; UV/Vis,  $\epsilon = 2.1 \times 10^3$   
 $\text{L} \cdot \text{mol}^{-1} \cdot \text{cm}^{-1}$  (264 nm, EtOH, 25 °C, linear range: 0.05-0.20  
mg/mL); TLC,  $R_f = 0.00$  [hexane-EtOAc (5:1)],  $R_f = 0.07$   
[MeOH-CHCl<sub>3</sub> (100:5)],  $R_f = 0.19$  [MeOH-CHCl<sub>3</sub>-NH<sub>4</sub>OH  
(100:5:1)]; GC,  $t_R = 7.45$  min; MS, 261 (M<sup>+</sup>), 229, 215,  
25 201, 183, 164, 150, 138, 122, 101, 83, 75, 57, 42  
[CH<sub>2</sub>NHCH<sub>3</sub>]; <sup>1</sup>H NMR (HCl salt, CDCl<sub>3</sub> + 1 gtt MeOD)  $\delta$  2.56  
(m, 2H, NCH<sub>2</sub>), 2.60 (s, 3H, NCH<sub>3</sub>), 2.85 (t,  $J = 8.0$ ,  
2H, CHCH<sub>2</sub>), 4.11 (t,  $J = 8.0$ , 1H, CH), 6.87-6.98 (m, 4H,  
ArH), 7.06 (d,  $J = 7.7$ , 2H, Ar<sub>2,3</sub>H), 7.25 (dd,  $J_1 = 6$ ,  $J_2$

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= 8, ArH);  $^{13}\text{C}$  NMR (HCl salt,  $\text{CDCl}_3$  + 1 qt MeOD)  $\delta$  30.9  
( $\text{CH}_2$ ,  $\text{CHCH}_2$ ), 32.7 ( $\text{CH}_3$ ,  $\text{NCH}_3$ ), 47.6 ( $\text{CH}$ ,  $\text{CHCH}_2$ ), 47.8  
( $\text{CH}_2$ ,  $\text{CH}_2\text{N}$ ), 113.9 ( $J = 21$ ,  $\text{ArC}_{2,2}$  or  $\text{ArC}_{4,4}$ ), 114.5 (d,  $J$   
= 22,  $\text{ArC}_{2,2}$  or  $\text{ArC}_{4,4}$ ), 123.2 (d,  $J = 3$ ,  $\text{Ar-C}_{5,6}$ ), 130.3  
5 (d,  $J = 9$ ,  $\text{Ar-C}_{5,5}$ ), 144.7 (d,  $J = 7$ ,  $\text{Ar-C}_{1,1}$ ), 152.9 (d,  
 $J = 245$ ,  $\text{Ar-C}_{3,3}$ ); IR: KBr pellet ( $\text{cm}^{-1}$ ), 3436.9,  
2963.4, 2778.5, 2453.7, 1610.6, 1589.3, 1487.0, 1445.3,  
1246.0, 764.5; solubility: 2 g/mL ( $\text{H}_2\text{O}$ ), 1 g/mL (EtOH);  
anal. calcd. for  $\text{C}_{16}\text{H}_{17}\text{NF}_2 \cdot \text{HCl}$  (Karl Fischer: 0.25%  $\text{H}_2\text{O}$ ):  
10 C, 64.37; H, 6.11; N, 4.69; found: C, 64.14; H,  
6.13; N, 4.69.



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Compound 105 was prepared by selective reduction of its corresponding alkene by catalytic hydrogenation over Pd/C.

Compound 61 was prepared from  
5 2-bromo-4-fluoroanisole and 3-fluorobenzaldehyde as described for Compound 24. GC/EI-MS ( $R_t$  = 9.22 min)  $m/z$  (relative intensity) 277 ( $M^+$ , 74), 260 (46), 245 (35), 231 (44), 229 (34), 217 (24), 203 (28), 201 (31), 183 (28), 154 (24), 133 (19), 109 (100).

10 Compound 62 was prepared from 2-bromoanisole and 2-methoxybenzaldehyde as described for Compound 24. GC/EI-MS ( $R_t$  = 9.30 min)  $m/z$  (relative intensity) 271 ( $M^+$ , 100), 254 (17), 240 (23), 225 (40), 223 (45), 207 (22), 181 (32), 165 (31), 136 (48), 121 (98), 91 (83).

15 The synthesis of Compound 63 was accomplished as follows.

Alcohol A was obtained from 3-fluorobenzaldehyde as described for product A of the Compound 24 synthesis.

20 To alcohol A (10.275 g, 47 mmol) in 200 ml of ethanol was added 1.6 g of 10% Pd/C and 1 ml of concentrated HCl. This mixture was hydrogenated for 3 hr at 60 psi, then filtered and concentrated to give the diphenylmethane B.

25 Product B (2.01 g, 9.86 mmol) was dissolved in 20 ml of THF and cooled to  $-78^\circ\text{C}$ . Butyl lithium (4.4 ml, 10.8 mmol, 2.5 M in hexanes) was added slowly by syringe, and then the reaction stirred for another 30 min at  $-78^\circ\text{C}$ . To this orange solution was added cyclopentene  
30 oxide (0.9 ml, 10.3 mmol). The reaction was allowed to stir 3 hours while warming slowly to room temperature.

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The reaction was quenched with 150 ml of 10% HCl and extracted 3 times with ether. The ether layer was dried over sodium sulfate and concentrated to give 2.5 g of the alcohol C.

5           To the alcohol C (1 g, 3.5 mmol) in 10 ml of dry THF was added triphenylphosphine (1.37 g, 5.2 mmol) in 5 ml of THF and p-nitrobenzoic acid (0.87 g, 5.2 mmol) in 5 ml of THF. This solution was cooled to 0°C followed by the addition of DEAD (0.82 ml, 5.2 mmol),  
10 and allowed to stir overnight. The reaction was partitioned between water and ether. The ether was removed in vacuo and the resulting oil was chromatographed on silica gel in hexane/ethyl acetate to yield 365 mg of the cis-ester. This ester was  
15 hydrolyzed in methanol with potassium carbonate by stirring overnight. After removal of the methanol, the residue was taken up in ether, washed with water, dried over sodium sulfate and concentrated to give 250 mg of the cis alcohol D.

20           To the alcohol D (.25 g, 0.9 mmol) in 5 ml of dry THF was added triphenylphosphine (342 mg, 1.3 mmol) in 5 ml of THF and phthalimide (191.3 mg, 1.3 mmol) in 5 ml of THF. This solution was cooled to 0°C followed by the addition of DEAD (0.205 ml, 1.3 mmol), and  
25 allowed to stir overnight. The reaction was partitioned between water and ether. The ether was removed in vacuo and the resulting oil was chromatographed on silica gel in hexane/ethyl acetate to yield 100 mg of the phthalimide E.

30           To a solution of the phthalimide E (100 mg) in 20 ml of ethanol was added 8.8 mg of hydrazine hydrate.



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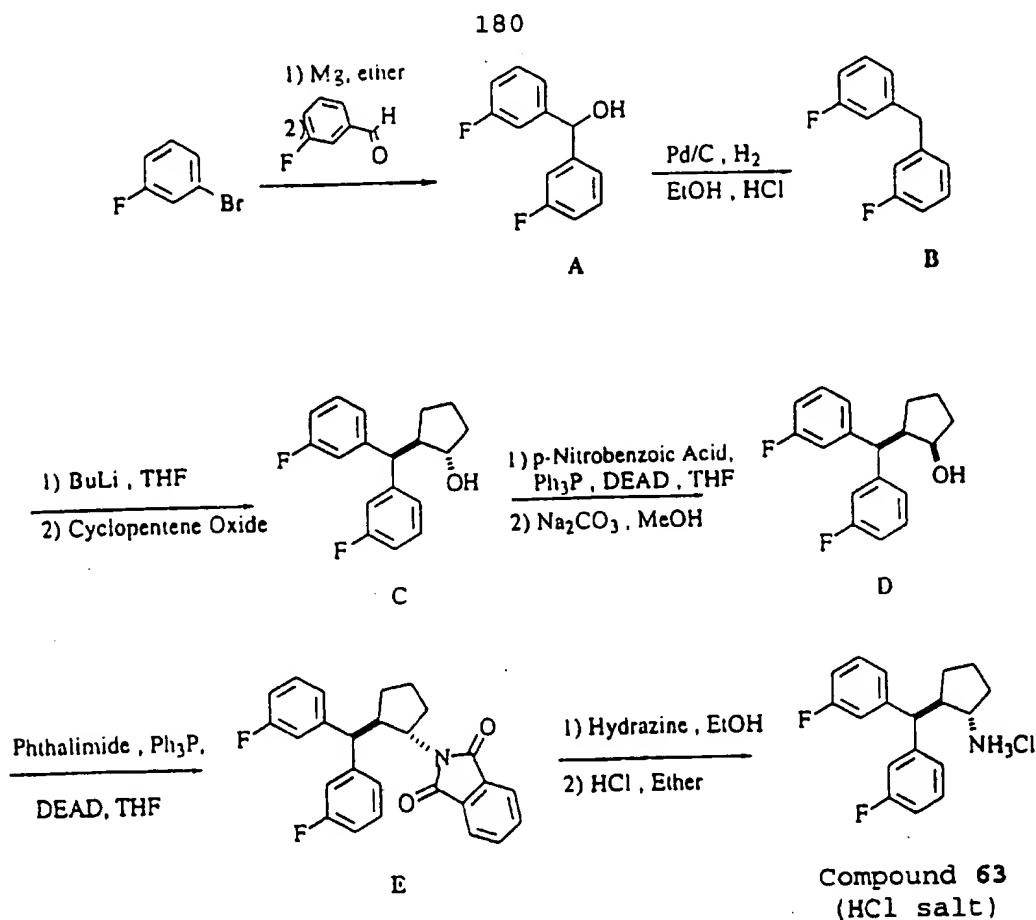
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The solution was refluxed for 5 hours then stirred at room temperature overnight. The reaction was worked up by adding 1 ml of conc. HCl and filtering off the white solid. The resulting solution was concentrated to dryness and the solid taken up in ether and aqueous sodium hydroxide. The ether layer was dried over sodium sulfate and concentrated to a white solid. This was taken up in a small amount of ether and treated with 10 drops of 1M HCl in ether. After stirring overnight, the white solid was collected by filtration and dried to give 50 mg of Compound 63, as the hydrochloride salt.

GC/EI-MS ( $R_t$  = 9.22 min)  $m/z$  (relative intensity)  
287 ( $M^+$ , 45), 270 (12), 201 (63), 183 (81), 133 (38), 109 (43), 83 (44), 56 (100), 43 (37).

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The synthesis of Compound 64 was done as described for Compound 63 except that the inversion step (product C to D) was omitted in order to obtain the cis amine as the final product. GC/EI-MS ( $R_t$  = 8.28 min)  $m/z$  (relative intensity) 287 ( $M^+$ , 15), 270 (4), 201 (13), 183 (15), 133 (11), 109 (16), 84 (43), 56 (100), 43 (32).

The synthesis of Compound 65 was accomplished as follows.

The ketone A was synthesized similarly to ketone B in the Compound 24 synthesis using 2-methylphenylmagnesium bromide and 2-methylbenzaldehyde as starting materials. This ketone was converted to the final product using the procedure outlined for Compound 58. GC/EI-MS ( $R_t$  = 7.84 min)  $m/z$  (relative intensity)

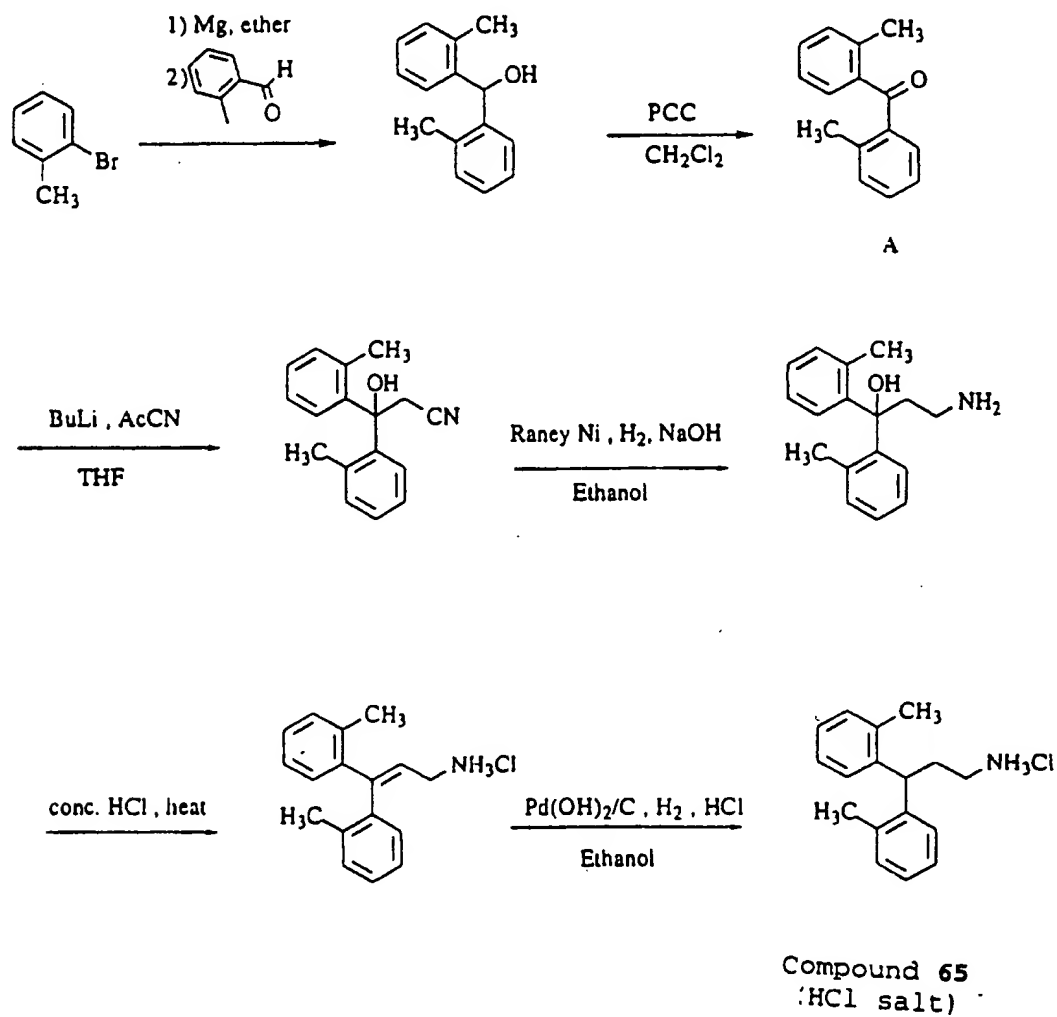
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239 (M<sup>+</sup>, 88), 222 (14), 207 (100), 193 (46), 178 (71),  
165 (60), 130 (39), 120 (40), 115 (51), 104 (40),  
91 (38), 77 (21).

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Compound 119 was synthesized in a seven-step reaction sequence starting from commercially-available trans-3-fluorocinnamic acid. This synthetic route is conceptually similar to that reported in the literature [U.S. Patent 4,313,896 (1982)] for related analogs. However, the three final steps were performed using a significantly different reaction sequence than that reported. The cinnamic acid was reduced and chlorinated in three steps to the corresponding 3-(3-fluorophenyl)propylchloride. This compound was brominated with NBS (*N*-bromosuccinimide) and the resulting trihalide was then reacted with 3-fluorophenol. The resulting ether was converted to the final product using a Gabriel synthesis.

Trans-3-fluorocinnamic acid (25.0 g, 150.4 mmol) was dissolved in abs. EtOH (250 mL) and hydrogenated over 10% Pd/C (2.5 g) in a Parr apparatus at 60 psig, 50°C, for 1 h (hydrogen uptake: calcd. 245 psig; found 260 psig). The reaction mixture was filtered and evaporated to yield a crystalline product (23.0 g, 89%). GC,  $t_R$  = 4.43 min; MS, 168 ( $M^+$ ).

Under a stream of dry nitrogen, at 0-10°C, a solution of 3-fluorohydrocinnamic acid (22.0 g, 131 mmol) in THF (100 mL) was added dropwise, over a period of 15 min, to a suspension of LiAlH<sub>4</sub> (4.23 g, 111 mmol) in THF (200 mL). The reaction was heated to reflux for a period of 1 h and then worked-up according to Fieser & Fieser's Reagents for Organic Synthesis (Vol. 1, 1967) to provide a white solid (20.1 g, 99%). GC,  $t_R$  = 3.74 min; MS, 154 ( $M^+$ ).

A solution of 3-(3-fluorophenyl)-1-propanol (15.0 g, 97.4 mmol) and triphenylphosphine (36.0 g,

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137.3 mmol) in  $\text{CCl}_4$  (150 mL) was refluxed for 19 h. Additional  $\text{P}(\text{C}_6\text{H}_5)_3$  (3 x 3.0 g, 3 x 11.4 mmol) was added periodically over a period of 24 h. The resulting precipitate was removed by filtration and the solids were washed with hexane. The filtrate was evaporated under vacuum and the residue was suspended in hexane (200 mL) and then filtered. Evaporation of the filtrate provided 16.0 g (95.1%) of crude product which was purification by silica gel flash chromatography, elution with hexane, to provide 14.7 g (87%) of a colorless liquid. GC,  $t_R = 3.63$  min; MS, 172/174 ( $\text{M}^+$ ).

A solution of the above chloride (12.0 g, 69.5 mmol), *N*-bromosuccinimide (17.3 g, 97.2 mmol), and dibenzoyl peroxide (0.06 g) in  $\text{CCl}_4$  (75 mL) was refluxed for 1 h. The reaction mixture was then cooled in an ice bath, filtered, and the solids were washed with hexane. The filtrate was evaporated to provide 17.9 g (100%) of product. GC,  $t_R = 5.21$  min; MS, 251/253 ( $\text{M}^+$ ).

A mixture of 3-bromo-3-(3-fluorophenyl)-1-propylchloride (4.0 g, 15.9 mmol), 3-fluorophenol (1.98 g, 17.7 mmol), and  $\text{K}_2\text{CO}_3$  (2.65 g, 19.2 mmol) suspended in acetone (80 mL) was refluxed for 15 h. The volatiles were then removed under vacuum and the resulting residue was suspended in a mixture of hexane (200 mL) and NaOH (0.1N, 100 mL). The layers were separated and the organic layer washed, 0.1N NaOH (100 mL) and  $\text{H}_2\text{O}$  (100 mL), dried (anh.  $\text{Na}_2\text{SO}_4$ ), and evaporated in *vacuo*. The resulting residue was chromatographed on silica gel, elution with hexane followed by hexane/EtOAc [100:1] then [40:1] to provide 1.64 g (37%) of product as a colorless oil. GC,  $t_R = 7.28$  min; MS, 282/283 ( $\text{M}^+$ ); TLC  $r_f = 0.3$ , hexane/EtOAc

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[40:1].

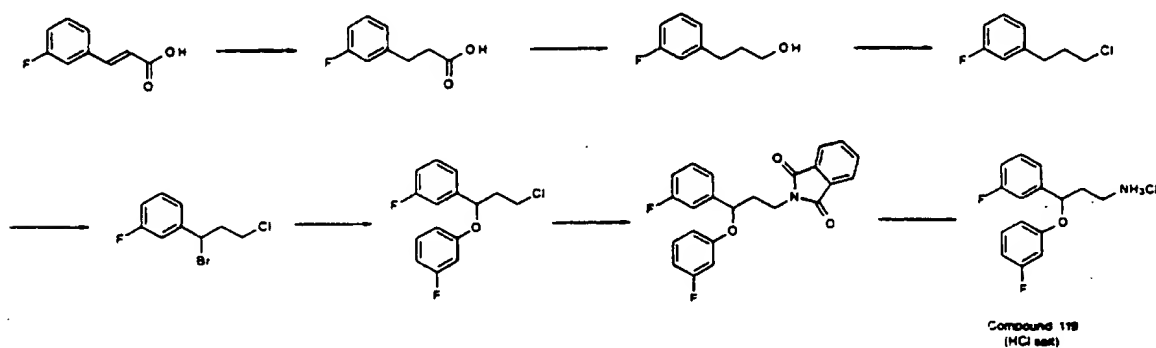
A solution of 3-(3-fluorophenyl)-3-(3-fluorophenoxy)-1-propylchloride (1.52 g, 5.38 mmol) and potassium phthalate (1.20 g, 6.48 mmol) was heated to 90°C in DMF (30 mL) for a period of 2 h in a nitrogen atmosphere. The reaction mixture was then cooled and poured into H<sub>2</sub>O (100 mL). The resulting solution was extracted with Et<sub>2</sub>O (2 x 100 mL). The organic extract was washed, sat. NaCl (100 mL) and H<sub>2</sub>O (2 x 100 mL), dried (anh. Na<sub>2</sub>SO<sub>4</sub>), and evaporated under vacuum to provide 2.17 g of crude product. The material was chromatographed on silica gel, elution with hexane/EtOAc [40:1] and then [20:1] to provide after evaporation 1.81 g (86%) of product as a glass.

A solution of *N*-phthaloyl-3-(3-fluorophenyl)-3-(3-fluorophenoxy)-1-propylamine (1.74 g, 4.42 mmol) and anh. hydrazine (1.43 g, 44.6 mmol) in abs. EtOH (30 mL) was refluxed for 1 h. The reaction was cooled and evaporated under vacuum. The resulting material was suspended in Et<sub>2</sub>O (75 mL) and washed with 0.2N NaOH (2 x 25 mL). The organic layer was dried (anh. Na<sub>2</sub>SO<sub>4</sub>), and evaporated under vacuum to provide 1.04 g (89.3%) which was purified by reverse-phase chromatography [Vydac Prep. C18; 264 nm; 50 mL/min; gradient elution ACN/0.1% HCl aq., 10%-50% over 20 min; *r<sub>t</sub>* = 17.4 min], to yield 0.89 g (67%) of Compound 119 as a hygroscopic hydrochloride salt.

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Compounds 118, 120-122 and 137 were prepared in a manner similar to the procedures used for the preparation of Compound 119.

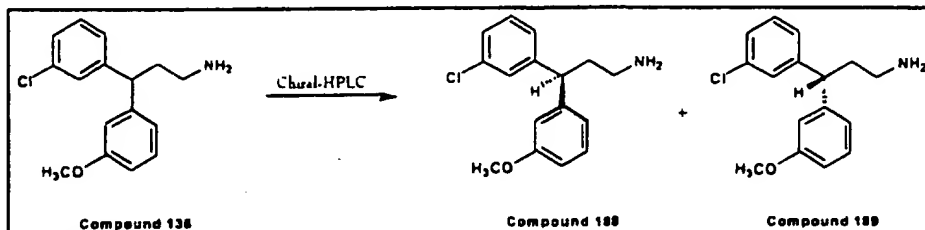
Compound 113 was synthesized from commercially available 4,4-diphenylcyclohexenone in three steps. First, the alkene in the starting material was reduced by means of catalytic hydrogenation. Methoxylamine formation followed by reduction using standard procedures.

The synthesis of Compounds 188 and 189 was accomplished as follows.

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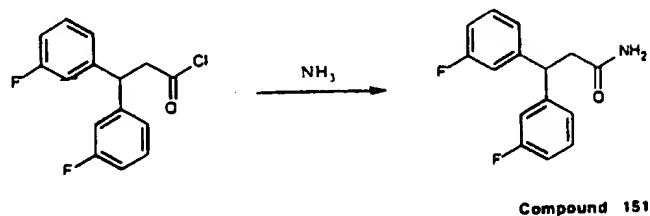
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### Compounds 188 and 189

The enantiomers of Compound 136 were separated by analytical chiral HPLC. Aliquots (20  $\mu$ g) were injected onto a Chiralcel-OD-R (Chiral Technologies, Inc., Exton, PA) reversed-phase HPLC column (0.46 x 250 mm) using the following conditions: gradient elution, 40%-70% ACN (60-30% 0.5N KTFA) over 30 min; flow rate, 1 mL/min; detector, 264 nm. Two identically-sized peaks were collected at 21.0 and 24.4 min. GC/MS analysis of the two samples indicate that both materials have identical GC retention times as well as identical mass spectra.

The synthesis of Compound 151 was accomplished as follows.





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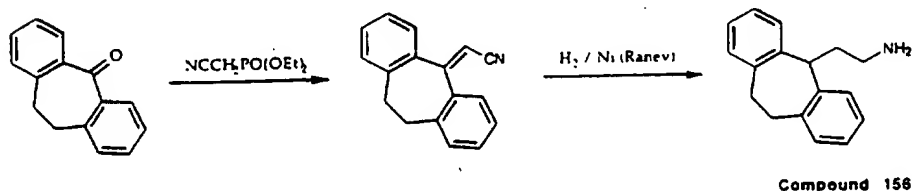
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*3,3-Bis(3-fluorophenyl)propanamide (Compound 151)*

A solution of liquid anh. ammonia (10 mL) in  $\text{CH}_2\text{Cl}_2$  (50 mL) at  $-78^\circ\text{C}$  was treated with a solution of 3,3-bis(3-fluorophenyl)propionyl chloride (2.19 g, 7.81 mmol) in  $\text{CH}_2\text{Cl}_2$  (25 mL). The reaction was then stirred at ambient temperature for 15 min and was then diluted with diethyl ether (500 mL), washed three times with 10% HCl, three times with 1N NaOH, and finally once with  $\text{H}_2\text{O}$ . The organic layer was dried (anh.  $\text{Na}_2\text{SO}_4$ ) and evaporated to give the primary amide as a white solid (2.01 g, 98%).

The synthesis of Compound 156 was accomplished as follows.

*5-Cyanomethylidino-10,11-dihydrodibenzo[a,d]cycloheptene*

To a solution of diethyl cyanomethylphosphonate (9.66 g, 54.5 mmol) in dry *N,N*-dimethylformamide (DMF, 40 mL) was added NaH (60% dispersion, 2.20 g, 55.0 mmol) over a period of 2 min. The reaction was stirred for 10 min and then a solution of dibenzosuberone (10.3 g, 49.6 mmol)

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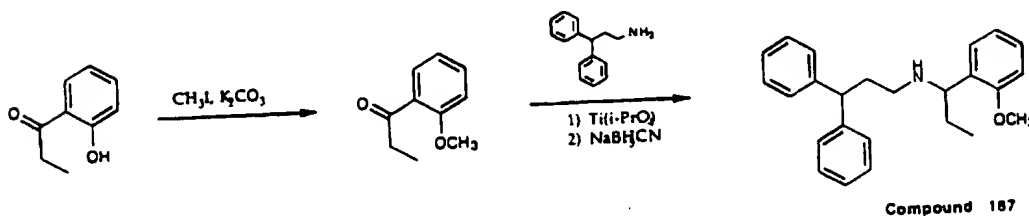
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in dry DMF (10 mL) was added over a period of 2 min. The reaction was stirred at 80°C for 4 h under N<sub>2</sub>. Water (200 mL) was added and the reaction mixture was extracted with Et<sub>2</sub>O (2 x 100 mL). The combined organic layers were rotary evaporated to less than 50 mL. The resulting crystals were collected and washed with cold Et<sub>2</sub>O (2 x 50 mL) to yield 7.48 g (65.3%).

*5-(2-Aminoethyl)-5H-10,11-dihydrodibenzo[a,d]cycloheptene hydrochloride (Compound 156)*

10      5-Cyanomethylidino-10,11-dihydrodibenzo[a,d]cycloheptene was dissolved in EtOH (100 mL). 1N NaOH (10 mL) and Raney® nickel (aq. suspension, 0.50 g) were added. The reaction mixture was shaken under 60 psig H<sub>2</sub> at 50°C for 22 h, and was then filtered through Celite®. The filtrate was rotary  
15 evaporated and the residue was dissolved in Et<sub>2</sub>O (100 mL), washed with satd. aq. NaCl (50 mL) and H<sub>2</sub>O (50 mL). The Et<sub>2</sub>O layer was dried (anh. Na<sub>2</sub>SO<sub>4</sub>) and rotary evaporated to give the crude product (850 mg) as a colorless oil. This oil was dissolved in EtOAc (5 mL) and filtered. 1.0M HCl (5 mL) in  
20 Et<sub>2</sub>O was added to the filtrate and a white, crystalline solid precipitated. This material was recrystallized from EtOH (5 mL)-Et<sub>2</sub>O (12 mL) to yield 600 mg (50.7%) of product as a white powder.

The synthesis of Compound 167 was accomplished as  
25 follows.



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*2-Methoxypropiophenone*

A mixture of 2-hydroxypropiophenone (3.00 g, 20.0 mmol), iodomethane (3.40 g, 24.0 mmol), and K<sub>2</sub>CO<sub>3</sub> (granular, anh.; 13.8 g, 99.9 mmol) was refluxed in acetone (75 mL) for 18 h. The reaction mixture was cooled to room temperature and the inorganic salts were removed by filtration. The filtrate was evaporated under vacuum to give an oil which was subsequently dissolved in diethyl ether (200 mL) and then washed with 0.1N NaOH (3 x 50 mL) followed by H<sub>2</sub>O (50 mL). The organic layer was dried (anh. Na<sub>2</sub>SO<sub>4</sub>), filtered, and evaporated to an orange oil (3.17 g, 96.9%). This material was used in the following step without further purification. TLC, R<sub>f</sub> 0.55 (1% MeOH:1% IPA:CHCl<sub>3</sub>); GC, tr 4.58 min; MS, m/z 164 (M+1).

15 *(R,S)-N-1-(2-methoxyphenylpropyl)-3,3-diphenylpropylamine*  
(Compound 167)

A solution of 2-methoxypropiophenone (0.848 g, 5.17 mmol), 3,3-diphenylpropylamine (1.00 g, 4.70 mmol), and titanium(IV) isopropoxide [Ti(OCH(CH<sub>3</sub>)<sub>2</sub>)<sub>4</sub>; (1.76 mL, 5.88 mmol, 1.25 equiv)] was stirred at room temperature for 6 h. EtOH (2 mL) was then added, followed by sodium cyanoborohydride (0.295 g, 4.70 mmol) in portions over a period of 10 min, and the reaction was then stirred for 18 h. The reaction mixture was then poured into diethyl ether (200 mL) and the resulting suspension was centrifuged to remove the titanium precipitate. The supernatant was collected and the pellet was rinsed with diethyl ether (200 mL). The combined organic washings were evaporated under vacuum to give a crude oil which was chromatographed on silica gel (elution with 4% MeOH-CH<sub>2</sub>Cl<sub>2</sub>) to provide 647 mg (38%) of product. The material was then dissolved in

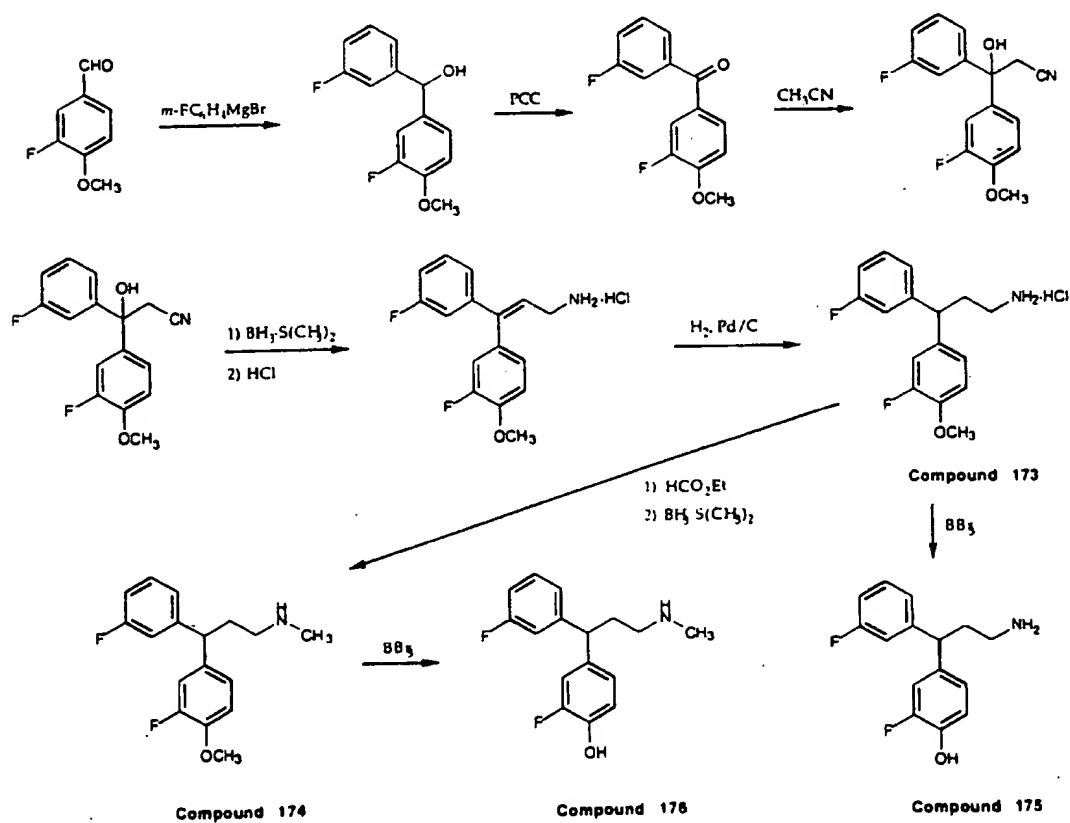
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diethyl ether (50 mL), filtered, and excess ethereal HCl was added to precipitate the hydrochloride salt (125 mg, 7.4%) as a white solid; TLC,  $R_f$  0.25 (4% MeOH-CH<sub>2</sub>Cl<sub>2</sub>); GC,  $t_r$  = 11.2 min; MS,  $m/z$  359 (M<sup>+</sup>).

- 5 The synthesis of Compounds 172 - 176 was accomplished as follows.



#### *R,S*)-3,3'-Difluoro-4-methoxybenzhydrol

A mixture of Mg<sup>0</sup> turnings (2.45 g, 101 mmol), 1-bromo-3-fluorobenzene (17.6 g, 100 mmol), and dry THF

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(200 mL) was carefully heated to reflux for 30 min. While still refluxing, 3-fluoro-*p*-anisaldehyde (15.3 g, 99.3 mmol) in THF (100 mL) was added over a period of 5 min. The reaction temperature was maintained for 30 min, cooled to room temperature, and then the reaction was quenched with satd. aq.  $\text{NH}_4\text{Cl}$  (200 mL). The organic layer was separated, washed with satd. aq.  $\text{NaCl}$  (2 x 200 mL), dried (anh.  $\text{Na}_2\text{SO}_4$ ), and rotary evaporated to yield 23.5 g (94.4%) of product as an orange-brown oil.

10 *3,3'-Difluoro-4-methoxybenzophenone*

Pyridinium chlorochromate (22.3 g, 103 mmol) was added to a solution of 3,3'-difluoro-4-methoxybenzhydrol (23.5 g, 93.8 mmol) in  $\text{CH}_2\text{Cl}_2$  (300 mL) and the reaction mixture was stirred for 16 h. Diethyl ether (500 mL) was added and the reaction mixture was filtered through Celite<sup>®</sup>. The filtrate was rotary evaporated and the resulting oil was flash chromatographed (gradient elution of hexanes to 1:1 hex-EtOAc). The TLC-pure fractions were rotary evaporated to yield 1.58 g of a white solid. The rest of the impure fractions containing product were combined and rotary evaporated to the point where crystals began to form. Additional hexane (300 mL) was added and the crystallizing solution was allowed to stand. The resulting crystals were collected and washed with hexanes (2 x 50 mL) to yield 6.81 g of product. The two batches were combined to afford a total yield of 8.39 g (36.1%).

*(R,S)- $\alpha$ -Cyanomethyl-3,3'-difluoro-4-methoxybenzhydrol*

To dry THF (100 mL) was added butyllithium (2.6M in heptane; 16.0 mL, 41.6 mmol) at  $-78^\circ\text{C}$ . Acetonitrile (2.20 mL, 42.1 mmol) was added over a period of 1 min and

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the reaction was stirred at  $-78^{\circ}\text{C}$  under  $\text{N}_2$  for 30 min. A solution of 3,3'-difluoro-4-methoxybenzophenone (8.38 g, 33.8 mmol) in anh. THF (50 mL) was added to the reaction over a period of 5 min and the solution was stirred at  $-78^{\circ}\text{C}$  for 30 min. The cold bath was removed and the reaction was allowed to warm for 30 min. Satd. aq.  $\text{NH}_4\text{Cl}$  (100 mL) was added to quench the reaction. The THF layer was separated, washed with satd. aq.  $\text{NaCl}$  (2 x 25 mL), dried (anh.  $\text{Na}_2\text{SO}_4$ ), rotary evaporated, and dried under vacuum to yield 10.1 g (103%) of product as a yellow oil.

(E)- and (Z)-3-(3-Fluoro-4-methoxy)-3-

(3-fluorophenyl)allylamine hydrochloride (Compound 172)

(R,S)- $\alpha$ -Cyanomethyl-3,3'-difluoro-4-methoxybenzhydrol (9.77 g, 33.8 mmol) was dissolved in dry THF (200 mL) and heated to boiling (no condenser). Under a stream of nitrogen, borane-dimethyl sulfide complex ( $\text{BH}_3\cdot\text{S}(\text{CH}_3)_2$ , 10.1M; 16.8 mL, 170 mmol) was added carefully over a period of 2 min to the boiling solution. Boiling was then maintained for 15 min until most of the THF was gone. The reaction mixture was then cooled in an ice bath. Ice (10 g) was carefully added, followed by  $\text{H}_2\text{O}$  (50 mL). The reaction was then heated to near boiling and 12.1N  $\text{HCl}$  (100 mL) was added. The reaction was boiled (no condenser) for 30 min and was then cooled in an ice bath, basified with 10N  $\text{NaOH}$  (100 mL), and extracted twice with  $\text{Et}_2\text{O}$  (200 mL, 100 mL). The combined ether layers were washed with 1N  $\text{NaOH}$  (50 mL) and  $\text{H}_2\text{O}$  (50 mL), dried (anh.  $\text{Na}_2\text{SO}_4$ ), and rotary evaporated. The resulting oil was flash chromatographed ( $\text{CHCl}_3$ ; 1:100 MeOH- $\text{CHCl}_3$ ; 1:10 MeOH- $\text{CHCl}_3$ ) through flash silica gel to afford 6.83 g of a yellow oil. This oil was dissolved in

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EtOH (2 mL) and Et<sub>2</sub>O (10 mL). 1.0M HCl in Et<sub>2</sub>O (27 mL) was added and the solution was rotary evaporated to yield 7.10 g (67.5%) of product as a solid, yellow foam.

(*R,S*)-3-(3-Fluoro-4-methoxy)-3-(3-fluorophenyl)propylamine  
5 maleate (Compound 173)

The mixture of (*E*)- and (*Z*)-3-(3-fluoro-4-methoxy)-3-(3-fluorophenyl)-allylamine hydrochlorides (7.10 g, 22.8 mmol) was dissolved in EtOH (200 mL) and a suspension of palladium on charcoal (10% Pd; 0.71 g) in H<sub>2</sub>O (3.5 mL) was added. The reaction mixture was then shaken  
10 under 60 psig H<sub>2</sub> for 18 h and subsequently filtered through Celite'. The filtrate was rotary evaporated, the residue was dissolved in EtOAc (25 mL) and Et<sub>2</sub>O (100 mL), and was basified with sat. aq. NaHCO<sub>3</sub> (25 mL). The organic layer was  
15 separated, dried (anh. Na<sub>2</sub>SO<sub>4</sub>), and rotary evaporated to yield 6.28 g of an oil. This oil and maleic acid (2.59 g) were dissolved into hot EtOAc (100 mL). Diethyl ether (70 mL) was added and crystals soon began to form. The crystals were collected and dried to yield 2.45 g (27.3%) of  
20 a white powder. The combined filtrate and washings afforded more crystalline product out upon standing. The second crop was filtered, washed with 1:1 EtOAc-Et<sub>2</sub>O (2 x 25 mL) and Et<sub>2</sub>O (1 x 25 mL), and dried to provide 3.69 g (41.2%) of a white powder. The total yield was thus 6.14 g (68.5%).

25 (*R,S*)-3-(3-Fluoro-4-methoxy)-3-(3-fluorophenyl)propylformamide

(*R,S*)-3-(3-Fluoro-4-methoxy)-3-(3-fluorophenyl)propyl amine maleate (3.12 g, 7.93 mmol) was free-based in a mixture of EtOAc (25 mL), Et<sub>2</sub>O (100 mL), and  
30 satd. aq. NaHCO<sub>3</sub> (25 mL). The organic layer was separated, dried (anh. Na<sub>2</sub>SO<sub>4</sub>), and rotary evaporated. A solution of

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the amine in ethyl formate (75 mL, 930 mmol) was refluxed for 17 h. The reaction solution was rotary evaporated to yield 2.38 g (98.3%) of formamide as a light-orange, viscous oil.

- 5 (R,S)-N-Methyl-3-(3-fluoro-4-methoxy)-3-(3-fluorophenyl)propyl amine maleate (Compound 174)  
(R,S)-3-(3-Fluoro-4-methoxy)-3-(3-fluorophenyl)propyl formamide (2.27, 7.43 mmol) in THF (100 mL) was heated to boiling (no condenser). Borane-  
10 dimethyl sulfide complex (10.1M; 2.30 mL, 23.2 mmol) was added carefully over a period of 2 min to the boiling solution. Boiling was then maintained for 15 min. The reaction was then cooled in an ice bath. Ice (10 g) was carefully added, followed by H<sub>2</sub>O (30 mL), followed by 12.1N  
15 HCl (50 mL). The reaction was then boiled (no condenser) for 30 min. The reaction was subsequently cooled in an ice bath, basified with 10N NaOH (50 mL), and extracted with Et<sub>2</sub>O (200 mL). The ether layer was washed with satd. aq. NaCl (100 mL), dried (anh. Na<sub>2</sub>SO<sub>4</sub>), and rotary evaporated to yield  
20 2.03 g of a yellow oil. This material was purified by RP-HPLC (20-60% acetonitrile-0.1% aq. HCl over 20 min). The collected fractions were frozen and lyophilized to yield 1.28 g of a white solid. The free-base of the purified amine was dissolved in EtOAc. Maleic acid (305 mg) was  
25 added and the mixture was heated until everything had dissolved. The product was crystallized by adding Et<sub>2</sub>O (5 mL). The crystals were filtered and washed with



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1:1 EtOAc-Et<sub>2</sub>O (10 mL) followed by Et<sub>2</sub>O (10 mL) to yield 967 mg of product as a white, finely crystalline solid. (R,S)-3-(3-Fluoro-4-hydroxy)-3-(3-fluorophenyl)propylamine maleate (Compound 175)

5 (R,S)-3-(3-Fluoro-4-methoxy)-3-(3-fluorophenyl)propyl-amine maleate (2.45 g, 6.23 mmol) was free-based in the normal manner and dissolved in CH<sub>2</sub>Cl<sub>2</sub> (25 mL). The resulting solution was cooled to -78°C. Under N<sub>2</sub> flow, boron tribromide (1.0M in CH<sub>2</sub>Cl<sub>2</sub>; 15 mL, 15 mmol) 10 was added over a period of 5 min. The cold bath was removed and the reaction mixture was allowed to warm to room temperature. After 30 min at 25°C, the reaction was hydrolyzed with 12.1N HCl (10 mL). The aqueous layer was neutralized (pH 7) by the careful addition of 10N NaOH 15 (14 mL). Satd. aq. NaHCO<sub>3</sub> (50 mL) was added along with Et<sub>2</sub>O (100 mL) and EtOAc (20 mL). This mixture was shaken vigorously and the organic layer was separated. The aqueous layer was extracted with EtOAc (20 mL). The combined organic layers were dried (anh. Na<sub>2</sub>SO<sub>4</sub>) and rotary 20 evaporated. The resulting oil was dissolved in EtOH, 1.0M HCl in Et<sub>2</sub>O (7 mL) was added, and the solution was rotary evaporated. This material was then purified by RP-HPLC [20-60% acetonitrile-0.1% HCl (aq.) over 20 min]. The collected fractions were frozen and lyophilized, 25 affording 716 mg of a white solid. The free-base of the purified amine (315 mg) was dissolved in EtOAc. Maleic acid (138 mg) was added and the mixture was heated until everything dissolved. The EtOAc was rotary evaporated to give a hard glass which was dissolved in MeOH (5 mL). Water 30 (100 mL) was then added and the solution was subsequently frozen and lyophilized. The above procedure yielded 445 mg

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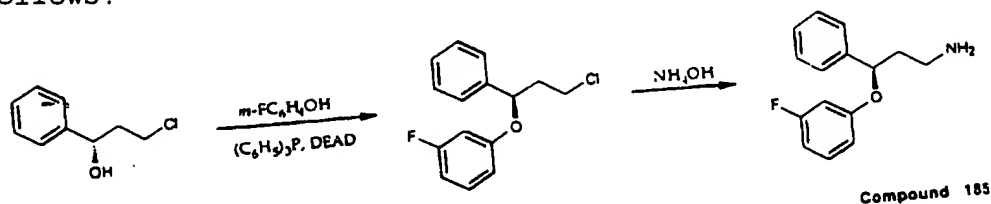
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of product as a white solid.

*(R,S)-N-Methyl-3-(3-fluoro-4-hydroxy)-3-(3-fluorophenyl)propyl amine hydrochloride (Compound 176)*

A solution of *(R,S)-N-methyl-3-(3-fluoro-4-methoxy)-3-(3-fluorophenyl)propylamine* (703 mg, 2.41 mmol) in  $\text{CH}_2\text{Cl}_2$  (10 mL) was cooled to  $-78^\circ\text{C}$ . Under nitrogen, boron tribromide (1.0M in  $\text{CH}_2\text{Cl}_2$ ; 6.0 mL, 6.0 mmol) was added over a period of 5 min. The cooling bath was then removed and the reaction was allowed to warm to room temperature. After 1 h, the reaction was quenched with 12.1N HCl (5 mL). The aqueous layer was then neutralized (pH 7) by the careful addition of 10N NaOH (~7 mL). Satd. aq.  $\text{NaHCO}_3$  (25 mL) was added along with  $\text{Et}_2\text{O}$  (50 mL),  $\text{EtOAc}$  (15 mL), and  $\text{CHCl}_3$  (5 mL). This mixture was shaken vigorously, and the organic layer was separated, dried (anh.  $\text{Na}_2\text{SO}_4$ ), and filtered through paper. The crude product was then purified by RP-HPLC (20-60% acetonitrile-0.1% aq. HCl gradient over 20 min). The fractions were frozen and lyophilized to afford 602 mg of product as a white solid.

The synthesis of Compound 185 was accomplished as follows.



*(R)-3-(3-Fluorophenoxy)-3-phenylpropylchloride*

Following a similar procedure for the chiral synthesis of fluoxetine [Srebnik, M. et al., *J. Org. Chem.* 53(13), 2916-20 (1988), hereby incorporated by reference herein], a solution of *(S)-(-)-3-chloro-1-phenyl-1-propanol*

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(4.00 g, 23.4 mmol), 3-fluorophenol (2.63 g, 23.4 mmol), and diethyl azodicarboxylate (4.00 g, 23.4 mmol) were dissolved in THF (200 mL). The mixture was cooled to 0°C and triphenylphosphine (6.77 g, 25.8 mmol, 1.1 equiv) was added  
5 slowly over 10 min. The reaction mixture was then stirred at room temperature for 18 h. The THF was subsequently evaporated under vacuum to afford a gel which was washed with pentane (3 x 50 mL). The pentane washings were filtered and the filtrate was evaporated under vacuum to  
10 give a clear oil. This oil was dissolved in diethyl ether (150 mL) and washed with 1% HCl-satd. NaCl (25 mL), 0.1N NaOH-satd. NaCl (2 x 25 mL), and finally H<sub>2</sub>O (2 x 25 mL). The organic layer was then dried (anh. Na<sub>2</sub>SO<sub>4</sub>), filtered, and evaporated to dryness under vacuum to give an orange oil.  
15 The crude product was chromatographed on silica gel (25 x 180 mm, gravity column), elution with 40:1 hexane-EtOAc, to provide 971 mg (15.7%) of product as a colorless oil.

*(R)-3-(3-Fluorophenoxy)-3-phenylpropylamine*

20 *(Compound 185)*

A solution of *(R)-3-(3-fluorophenoxy)-3-phenylpropyl chloride* (0.971 g, 3.96 mmol), conc. NH<sub>4</sub>OH (30 mL), and EtOH (20 mL) were shaken at 90°C on a Parr' apparatus (50-90 psig) for 18 h. The mixture was then  
25 evaporated under vacuum and the residue was dissolved in Et<sub>2</sub>O (100 mL) and washed with H<sub>2</sub>O (2 x 25 mL). The organic layer was dried (anh. Na<sub>2</sub>SO<sub>4</sub>), filtered, and evaporated under vacuum to provide a yellow oil. This material was then dissolved in EtOAc (50 mL) and filtered. A solution of  
30 maleic acid (0.272 g, 2.6 mmol, 0.93 equiv) dissolved in hot EtOAc (5 mL) was added to precipitate the maleate salt

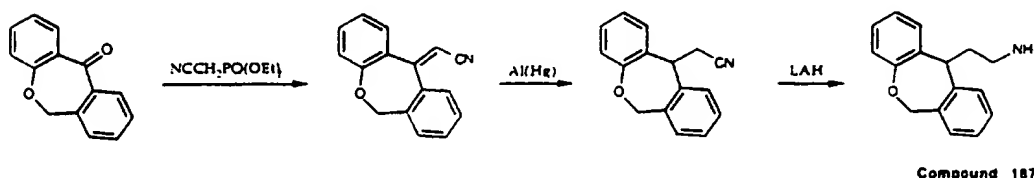
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(519 mg, 53.5%) as a white solid: TLC  $R_f$  0.25 (1% MeOH-CHCl<sub>3</sub>); GC,  $t_r$  7.37 min; MS,  $m/z$  245 (M<sup>+</sup>).

The synthesis of Compound 187 was accomplished as follows.



*11-Cyanomethylene-10,11-dihydrodibenzo[b,c]oxepine*

5 To a solution of diethyl cyanomethylphosphonate (5.06 g, 28.6 mmol) in dry DMF (15 mL) was added NaH (60% mineral oil dispersion; 1.14 g, 28.5 mmol) over a period of 2 min. The reaction was stirred for 10 min and then a solution of 6,11-dihydrodibenzo[b,c]oxepin-11-one [Kurokawa  
10 M. et al., Chem. Pharm. Bull. 39(10), 2564-2573 (1991), hereby incorporated by reference herein] (4.00 g, 19.0 mmol) in dry DMF (5 mL) was added. The reaction mixture was stirred under argon for 21 h. Water (100 mL) was then added and the product was extracted with EtOAc (2 x 50 mL). The  
15 combined organic layers were washed with satd. aq. NaCl (2 x 50 mL), dried (anh. Na<sub>2</sub>SO<sub>4</sub>), and rotary evaporated. The resulting solid was recrystallized from hot EtOAc (10 mL) - hexanes (40 mL) to provide 2.43 g (54.7%) of product.

*11-Cyanomethyl-10,11-dihydrodibenzo[b,c]oxepine*

20 Following a procedure described in Great Britain Patent 1,129,029 (1968) (Chem. Abstr. 70:37664), hereby incorporated by reference herein], for the preparation of aluminum amalgam, Al<sup>0</sup> granules (2.00 g, 74.1 mmol) were first etched with 0.5N NaOH (100 mL) and then washed with H<sub>2</sub>O  
25 (100 mL) followed by EtOH (100 mL). A solution of HgCl<sub>2</sub> (2.00 g, 7.37 mmol) in Et<sub>2</sub>O (100 mL) was added. The reaction

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mixture was stirred for 5 min and the supernatant was decanted. The solid Al(Hg) amalgam was washed with H<sub>2</sub>O (100 mL), EtOH (100 mL), and then Et<sub>2</sub>O (100 mL). The amalgam was covered with Et<sub>2</sub>O (100 mL) and a solution of

5 11-cyanomethylene-10,11-dihydrodibenzo[b,c]oxepine (2.00 g, 8.57 mmol) in EtOAc (30 mL) and EtOH (20 mL) was added. Water (2 mL) was added and the reaction mixture was stirred for 18 h and then filtered. The filtrate was rotary evaporated to yield 1.65 g (81.8%) of product as a white,

10 crystalline solid.

*11-(2-Aminoethyl)-11H-10,11-dihydrodibenzo[b,c]oxepine hydrochloride (Compound 187)*

To a stirring suspension of lithium aluminum hydride (0.67 g, 18 mmol) in anh. Et<sub>2</sub>O (30 mL) was added a

15 solution of 11-cyanomethyl-11H-10,11-dihydrodibenzo[b,c]oxepine (1.65 g, 7.01 mmol) in dry THF (5 mL)/anh. Et<sub>2</sub>O (10 mL) over a period of 2 min. The reaction was stirred for 30 min. In the following order, H<sub>2</sub>O (0.7 mL), 5N NaOH (0.7 mL), and H<sub>2</sub>O (2.1 mL) were added to the reaction

20 mixture. Diethyl ether (30 mL) was added and the mixture was filtered. The filtrate was rotary evaporated and the resulting oil was dissolved in EtOH (10 mL)-Et<sub>2</sub>O (65 mL). 1.0M HCl in Et<sub>2</sub>O (10 mL) was added and the solution was allowed to crystallize, giving 1.42 g (73.4 %) of the title

25 compound.

Compounds 67-68, 70-75, 79-82, 84-89, 91-95, 98-100, 102, 104-106, 109-114, 117, 124-134, 138, and 140-150 were synthesized by standard procedures known to those skilled in the art, as described above.

### 30 Gas Chromatography of Simplified Arylalkylamines

Gas chromatographic and mass spectral data were

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obtained on a Hewlett-Packard 5890 Series II Gas Chromatograph equipped with a 5971 Series Mass Selective Detector [Ultra-2 Ultra Performance Capillary Column (cross-linked 5% phenyl methyl silicone); column length, 25 m, column i.d., 0.20 mm; The flow rate, 60 mL/min; injector temp., 250°C; gradient temperature program, 20°C/min from 125 to 325°C for 10 min, then held constant at 325°C for 6 min].

Compound 19. (Rt = 7.40 min), m/z (rel. int.) 211 (M+,13), 195 (16), 194 (100), 193 (73), 180 (8), 179 (33), 178 (19), 168 (24), 167 (50), 166 (23), 165 (72), 164 (8), 153 (10), 152 (31), 117 (13), 116 (38), 115 (26), 106 (14), 104 (14), 103 (24), 102 (8), 91 (11), 78 (14), 77 (29), 63 (9), 51 (17)

Compound 20. (Rt = 7.34 min), m/z (rel. int.) 247 (M+,27), 231 (16), 230 (100), 229 (45), 215 (29), 214 (14), 204 (43), 203 (37), 202 (13), 201 (47), 184 (14), 183 (58), 181 (8), 151 (9), 135 (13), 134 (31), 133 (25), 124 (18), 122 (16), 121 (19), 109 (15), 101 (29), 96 (18), 95 (11), 83 (11), 75 (20), 57 (10), 42 (9)

Compound 21. (Rt = 7.53 min), m/z (rel. int.) 261 (M+,69), 262 (13), 245 (17), 244 (100), 230 (11), 229 (42), 216 (11), 215 (15), 214 (14), 204 (45), 203 (35), 202 (16), 201 (63), 184 (12), 183 (61), 148 (11), 136 (9), 135 (27), 133 (36), 124 (21), 115 (16), 109 (43), 83 (12), 74 (8), 58 (14), 57 (11)

Compound 22. (Rt = 7.37 min), m/z (rel. int.) 261 (M+,4), 244 (14), 229 (7), 204 (10), 203 (16), 201 (12), 183 (16), 138 (4), 133 (5), 109 (4), 101 (7), 75 (4), 58 (8), 57 (4), 44 (100), 42 (7)

Compound 24. (Rt = 8.21 min), m/z (rel. int.) 259 (M+,122), 260 (23), 242 (44), 241 (15), 228 (15), 227 (49), 216 (15),

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213 (56), 212 (16), 211 (55), 199 (32), 196 (22), 185 (34),  
184 (19), 183 (67), 171 (16), 170 (38), 165 (44), 151 (20),  
150 (16), 146 (13), 136 (46), 134 (17), 133 (37), 123 (15),  
121 (22), 120 (13), 109 (100), 91 (34), 77 (29), 51 (15)

5 Compound 25. (Rt = 8.49 min), m/z (rel. int.) 259 (M+,39),  
243 (16), 242 (95), 241 (25), 227 (27), 217 (15), 216 (100),  
215 (27), 212 (13), 211 (50), 201 (14), 200 (11), 199 (15),  
196 (15), 185 (20), 184 (19), 183 (50), 171 (24), 170 (28),  
165 (15), 146 (10), 136 (11), 134 (12), 133 (23), 121 (21),  
10 77 (9)

Compound 26. (Rt = 8.69 min), m/z (rel. int.) 259 (M+,11),  
243 (17), 242 (100), 241 (69), 227 (10), 215 (31), 212 (11),  
211 (52), 184 (14), 183 (31), 172 (13), 171 (35), 170 (23),  
165 (13), 147 (21), 146 (12), 134 (19), 133 (23), 121 (13),  
15 91 (11), 77 (10)

Compound 27. (Rt = 8.80 min), m/z (rel. int.) 243 (M+,54),  
226 (36), 212 (12), 211 (69), 200 (14), 199 (16), 198 (20),  
197 (100), 196 (39), 185 (35), 184 (30), 183 (50), 179 (13),  
178 (14), 165 (13), 134 (15), 133 (19), 120 (29), 117 (16),  
20 115 (27), 104 (13), 101 (11), 91 (23), 77 (13)

Compound 28. (Rt = 8.77 min), m/z (rel. int.) 243 (M+,25),  
227 (15), 226 (85), 225 (26), 212 (19), 211 (100), 200 (22),  
199 (17), 197 (18), 196 (29), 185 (46), 184 (35), 183 (64),  
179 (9), 165 (11), 134 (19), 133 (23), 121 (12), 120 (18),  
25 117 (14), 115 (24), 101 (12), 91 (25), 77 (12), 65 (11), 51  
(9)

Compound 29. (Rt = 7.89 min), m/z (rel. int.) 243 (M+,12),  
227 (9), 226 (52), 225 (17), 212 (19), 211 (100), 199 (13),  
197 (12), 196 (21), 185 (19), 184 (24), 183 (43), 179 (7),  
30 134 (11), 133 (15), 120 (9), 117 (10), 115 (17), 91 (14)

Compound 30. (Rt = 8.36 min), m/z (rel. int.) 263 (M+,21),

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246 (26), 220 (13), 212 (17), 211 (100), 197 (10), 196 (25),  
185 (43), 184 (30), 183 (69), 181 (9), 165 (12), 133 (18),  
115 (14), 101 (15), 75 (15)

Compound 31. (Rt = 9.31 min), m/z (rel. int.) 279 (M+,18),  
5 281 (11), 262 (10), 236 (10), 229 (33), 228 (17), 227 (100),  
203 (9), 201 (33), 199 (15), 192 (15), 178 (19), 166 (18),  
165 (53), 164 (13), 163 (16), 140 (12), 115 (13), 103 (9)

Compound 32. (Rt = 7.30 min), m/z (rel. int.) 229 (M+,21),  
213 (16), 212 (100), 211 (61), 197 (33), 196 (19), 194 (14),  
10 186 (26), 185 (30), 184 (19), 183 (69), 170 (17), 166 (16),  
165 (77), 134 (25), 133 (23), 116 (17), 115 (17), 103 (18),  
101 (11), 78 (13), 77 (23), 75 (13), 51 (18), 43 (13), 42  
(13)

Compound 33. (Rt = 7.56 min), m/z (rel. int.) 261 (M+,68),  
15 245 (18), 244 (100), 229 (43), 215 (16), 214 (15), 204 (57),  
203 (43), 202 (15), 201 (64), 184 (14), 183 (73), 148 (16),  
136 (13), 135 (46), 133 (60), 124 (51), 115 (27), 111 (14),  
109 (96), 107 (16), 96 (14), 83 (27), 75 (20), 58 (96), 57  
(33), 56 (23), 41 (35)

Compound 34. (Rt = 7.39 min), m/z (rel. int.) 261 (M+,72),  
262 (14), 245 (18), 244 (100), 229 (42), 216 (9), 215 (15),  
214 (14), 204 (52), 203 (38), 202 (14), 201 (54), 184 (12),  
183 (62), 181 (10), 148 (13), 136 (9), 135 (31), 133 (40),  
124 (30), 115 (18), 109 (57), 107 (9), 83 (13), 58 (21), 57  
25 (11)

Compound 35. (Rt = 4.45 min), m/z (rel. int.) 181 (M+,8),  
165 (10), 164 (76), 138 (48), 136 (11), 135 (63), 133 (12),  
123 (22), 122 (22), 121 (11), 110 (21), 109 (100), 101 (13),  
96 (27), 83 (14), 75 (11), 56 (15), 45 (21), 44 (40), 42  
30 (9), 41 (15)

Compound 37. (Rt = 4.87 min), m/z (rel. int.) 196 (M+,4),



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195 (17), 178 (76), 163 (20), 152 (41), 150 (22), 137 (12),  
136 (29), 135 (60), 133 (19), 124 (13), 123 (20), 122 (49),  
121 (17), 110 (78), 109 (100), 101 (17), 96 (29), 83 (17),  
75 (12), 56 (29), 55 (12), 45 (53), 44 (45), 43 (39), 41

5 (30)

Compound 38. (Rt = 7.68 min), m/z (rel. int.) 275 (M+, .1),  
203 (5), 201 (6), 183 (8), 135 (4), 133 (4), 109 (8), 71  
(3), 45 (3), 44 (100), 42 (4)

Compound 39. (Rt = 7.67min), m/z (rel. int.) 289 (M+, 6), 203  
10 (3), 201 (5), 183 (6), 135 (2), 133 (3), 109 (7), 85 (3), 70  
(3), 59 (4), 58 (100)

Compound 40. (Rt = 7.63min), m/z (rel. int.) 289 (M+, 19);  
203 (6), 201 (13), 183 (17), 152 (5), 135 (6), 133 (8), 109  
(15), 85 (5), 70 (4), 58 (100)

15 Compound 41. (Rt = 7.93 min), m/z (rel. int.) 275 (M+, 23),  
258 (20), 203 (27), 202 (14), 201 (52), 184 (9), 183 (59),  
181 (10), 150 (11), 149 (18), 147 (11), 135 (24), 134 (14),  
133 (40), 124 (12), 123 (19), 109 (76), 107 (9), 103 (10),  
83 (15), 75 (10), 72 (100), 71 (12), 57 (18), 56 (21), 55  
20 (41)

Compound 43. (Rt = 9.18 min), m/z (rel. int.) 293 (M+, 11),  
276 (10), 243 (11), 241 (31), 236 (11), 235 (16), 201 (18),  
199 (22), 179 (11), 178 (25), 176 (10), 166 (16), 165 (70),  
164 (19), 163 (24), 103 (9), 102 (9), 75 (11), 44 (100), 43

25 (11), 42 (15)

Compound 46. (Rt = 9.34 min), m/z (rel. int.) 293 (M+, 46),  
295 (28), 276 (16), 243 (24), 242 (15), 241 (75), 237 (12),  
236 (18), 201 (33), 199 (31), 178 (26), 176 (13), 166 (31),  
165 (100), 164 (32), 163 (43), 152 (11), 151 (13), 149 (12),  
30 140 (30), 139 (11), 129 (12), 127 (20), 125 (31), 117 (26),  
116 (26), 115 (64), 91 (12), 89 (17), 77 (13), 75 (22), 63

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(14), 58 (51), 57 (15), 56 (19), 41 (19)

Compound 50. (Rt = 7.37 min), m/z (rel. int.) 261 (M+,2),  
244 (9), 229 (4), 204 (7), 203 (11), 201 (8), 183 (11), 101  
(5), 58 (7), 44 (100), 42 (7)

5 Compound 51. (Rt = 7.30 min), m/z (rel. int.) 261 (M+,5),  
244 (20), 229 (9), 204 (14), 203 (23), 202 (6), 201 (20),  
183 (27), 133 (7), 121 (6), 101 (9), 75 (6), 58 (7), 44  
(100), 43 (6), 42 (11)

Compound 52. (Rt = 7.24 min), m/z (rel. int.) 247 (M+,56),  
10 231 (13), 230 (81), 229 (47), 216 (12), 215 (32), 214 (16),  
204 (29), 203 (31), 202 (16), 201 (63), 196 (21), 184 (20),  
183 (100), 182 (11), 181 (15), 170 (13), 151 (13), 150 (11),  
135 (13), 134 (29), 133 (25), 124 (14), 122 (20), 121 (21),  
109 (13), 101 (27), 96 (21), 75 (23), 43 (14), 42 (15)

15 Compound 53. (Rt = 7.21 min), m/z (rel. int.) 247 (M+,98),  
248 (17), 231 (13), 230 (84), 229 (56), 215 (38), 214 (16),  
203 (33), 202 (16), 201 (68), 196 (26), 184 (16), 183 (100),  
181 (15), 151 (21), 150 (15), 135 (14), 134 (35), 133 (24),  
124 (19), 122 (23), 121 (25), 111 (13), 101 (31), 96 (19),  
20 75 (19)

Compound 55. (Rt = 7.86 min), m/z (rel. int.) 275 (M+,98),  
276 (20), 258 (59), 229 (58), 216 (31), 215 (22), 214 (19),  
204 (49), 203 (41), 202 (21), 201 (82), 184 (18), 183 (100),  
181 (14), 150 (21), 135 (33), 133 (55), 124 (41), 115 (13),  
25 109 (90), 101 (15), 83 (20), 75 (16), 72 (23), 57 (13), 56  
(24)

Compound 56. (Rt = 7.79 min), m/z (rel. int.) 261 (M+,67),  
262 (12), 244 (54), 229 (56), 218 (27), 217 (16), 216 (19),  
215 (100), 214 (45), 203 (50), 202 (32), 201 (51), 197 (16),  
30 196 (26), 183 (24), 138 (17), 135 (20), 134 (17), 133 (39),  
122 (26), 121 (13), 109 (30), 101 (17), 96 (14), 83 (16), 75

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(13)

Compound 57. (Rt = 7.65min), m/z (rel. int.) 261 (M+,62),  
244 (50), 229 (50), 218 (24), 217 (13), 216 (18), 215 (100),  
214 (36), 203 (42), 202 (19), 201 (33), 197 (14), 196 (19),  
5 183 (17), 138 (19), 135 (16), 134 (12), 133 (29), 122 (29),  
109 (25), 101 (13)

Compound 58. (Rt = 8.15 min), m/z (rel. int.) 275 (M+,134),  
276 (26), 258 (23), 244 (19), 243 (100), 232 (25), 229 (53),  
217 (51), 216 (23), 215 (67), 214 (97), 201 (44), 197 (21),  
10 196 (43), 183 (23), 148 (38), 147 (21), 138 (46), 135 (46),  
134 (18), 133 (64), 125 (25), 123 (28), 122 (81), 115 (27),  
109 (54), 107 (17), 83 (27), 44 (19), 43 (19)

Compound 59. (Rt = 7.61 min), m/z (rel. int.) 275 (M+,27),  
204 (8), 203 (10), 201 (19), 183 (25), 109 (8), 101 (7), 58  
15 (100), 57 (8), 56 (8), 44 (9)

Compound 60. (Rt = 7.34 min), m/z (rel. int.) 261 (M+,55),  
262 (10), 204 (16), 203 (15), 201 (31), 183 (35), 133 (11),  
122 (11), 121 (10), 109 (9), 101 (16), 96 (11), 75 (10), 57  
(9), 44 (100), 42 (11)

20 Compound 61. (Rt = 8.07min), m/z (rel. int.) 277 (M+,68),  
278 (13), 260 (31), 246 (11), 245 (25), 234 (12), 231 (32),  
229 (26), 217 (20), 203 (23), 201 (24), 188 (12), 183 (22),  
154 (24), 151 (15), 150 (10), 133 (18), 124 (10), 109 (100),  
95 (11), 44 (14)

25 Compound 62. (Rt = 8.93 min), m/z (rel. int.) 271 (M+,115),  
272 (22), 254 (16), 239 (22), 225 (36), 223 (40), 181 (33),  
165 (34), 153 (13), 152 (24), 136 (39), 132 (13), 131 (16),  
123 (20), 122 (13), 121 (89), 119 (13), 115 (23), 105 (17),  
91 (100), 77 (22)

30 Compound 63. (Rt = 8.47min), m/z (rel. int.) 287 (M+,31),  
241 (9), 204 (27), 203 (20), 202 (9), 201 (30), 183 (38),

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150 (13), 133 (20), 109 (27), 84 (45), 83 (43), 82 (11), 57 (18), 56 (100), 43 (25)

Compound 64. (Rt = 8.57 min), m/z (rel. int.) 287 (M+,63), 288 (13), 270 (14), 242 (16), 241 (17), 215 (17), 214 (18),  
5 204 (35), 203 (27), 202 (18), 201 (70), 183 (86), 150 (18), 147 (16), 146 (17), 135 (16), 133 (45), 109 (45), 84 (31), 83 (38), 82 (13), 75 (15), 57 (21), 56 (100), 43 (44)

Compound 65. (Rt = 8.18 min), m/z (rel. int.) 239 (M+,88), 240 (17), 222 (12), 208 (18), 207 (100), 195 (24), 193 (48),  
10 192 (11), 181 (33), 180 (32), 179 (57), 178 (72), 166 (16), 165 (60), 152 (13), 130 (36), 129 (17), 120 (40), 117 (34), 116 (14), 115 (53), 107 (20), 105 (19), 104 (42), 103 (11), 91 (37), 77 (20), 65 (17)

Compound 66. (Rt = 7.46 min), m/z (rel. int.) 275 (M+,7),  
15 201 (5), 183 (6), 133 (3), 109 (6), 71 (3), 45 (3), 44 (100), 42 (3)

Compound 67. (Rt = 7.56 min), m/z (rel. int.) 225 (M+,24), 194 (8), 193 (12), 179 (6), 168 (10), 167 (12), 166 (6), 165 (20), 152 (9), 120 (8), 116 (6), 115 (7), 103 (7), 77 (8),  
20 51 (5), 44 (100)

Compound 68. (Rt = 7.85 min), m/z (rel. int.) 239 (M+,22), 194 (5), 193 (10), 168 (10), 167 (12), 166 (6), 165 (19), 152 (9), 134 (6), 116 (5), 115 (7), 91 (7), 77 (6), 59 (5), 58 (100), 44 (8)

25 Compound 69. (Rt = 7.35min), m/z (rel. int.) 275 (M+,11), 203 (24), 202 (7), 201 (23), 183 (35), 122 (6), 121 (6), 101 (9), 58 (100), 57 (8), 56 (10)

Compound 72. (Rt = 7.90 min), m/z (rel. int.) 253 (M+,25), 238 (9), 193 (7), 168 (8), 167 (14), 165 (17), 152 (9), 115  
30 (7), 91 (11), 73 (8), 72 (100), 58 (45), 56 (7), 44 (6), 43 (9), 42 (8)

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Compound 73. (Rt = 7.29 min), m/z (rel. int.) 239 (M+,9),  
240 (2), 167 (2), 165 (5), 152 (2), 115 (2), 77 (2), 59 (5),  
58 (100), 44 (3), 42 (5)

Compound 74. (Rt = 8.01 min), m/z (rel. int.) 267 (M+,7),  
5 167 (3), 165 (6), 152 (3), 91 (4), 87 (7), 86 (100), 72  
(13), 58 (10), 56 (4), 42 (4)

Compound 79. (Rt = 7.89 min), m/z (rel. int.) 230 (M+,37),  
214 (15), 213 (100), 212 (62), 201 (26), 200 (72), 198 (21),  
195 (12), 188 (17), 187 (85), 186 (46), 185 (42), 184 (9),  
10 157 (12), 135 (9), 133 (24), 109 (10), 107 (20), 106 (62),  
80 (14), 79 (32), 78 (9), 51 (20)

Compound 81. (Rt = 7.40 min), m/z (rel. int.) 209 (M+,89),  
210 (14), 208 (100), 193 (17), 192 (56), 191 (42), 189 (12),  
178 (20), 166 (11), 165 (45), 152 (12), 132 (86), 131 (10),  
15 130 (53), 117 (22), 115 (48), 106 (22), 105 (10), 104 (12),  
103 (16), 91 (16), 77 (22), 51 (15)

Compound 82. (Rt = 7.93min), m/z (rel. int.) 275 (M+,124),  
276 (25), 232 (33), 215 (12), 214 (16), 204 (14), 203 (100),  
201 (24), 196 (8), 183 (20), 150 (14), 138 (9), 136 (14),  
20 135 (44), 133 (26), 125 (9), 124 (71), 123 (29), 121 (14),  
115 (14), 111 (72), 110 (9), 109 (84), 101 (14), 83 (9), 75  
(8)

Compound 83. (Rt = 7.22 min), m/z (rel. int.) 235 (M+,10),  
219 (17), 218 (100), 217 (62), 203 (20), 192 (10), 191 (38),  
25 190 (7), 189 (14), 185 (17), 183 (7), 171 (9), 165 (8), 147  
(10), 146 (11), 134 (12), 133 (17), 121 (8), 109 (8), 97  
(8), 45 (7)

Compound 85. (Rt = 7.73 min), m/z (rel. int.) 239 (M+,7),  
222 (15), 179 (8), 178 (9), 168 (16), 167 (33), 166 (12),  
30 165 (43), 161 (9), 152 (20), 146 (17), 129 (7), 120 (15),  
118 (7), 117 (19), 115 (25), 91 (25), 77 (7), 72 (9), 44

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(100), 42 (6)

Compound 86. (Rt = 7.66 min), m/z (rel. int.) 239 (M+,3),  
222 (4), 168 (4), 167 (11), 166 (4), 165 (14), 152 (7), 120  
(6), 117 (6), 115 (8), 91 (9), 72 (5), 44 (100), 42 (3)

5 Compound 87. (Rt = 7.33 min), m/z (rel. int.) 239 (M+,4),  
222 (9), 179 (9), 178 (11), 168 (11), 167 (27), 166 (13),  
165 (48), 161 (7), 152 (22), 146 (14), 128 (7), 120 (11),  
118 (8), 117 (21), 115 (31), 91 (29), 77 (9), 72 (8), 51  
(7), 44 (100), 42 (9)

10 Compound 88. (Rt = 7.4 min), m/z (rel. int.) 227 (M+, .0),  
183 (10), 168 (18), 167 (100), 166 (32), 165 (83), 164 (10),  
163 (6), 153 (6), 152 (35), 139 (6), 115 (8), 105 (9), 77  
(12), 51 (7), 45 (23)

Compound 89. (Rt = 8.74 min), m/z (rel. int.) 260 (M+,220),  
15 261 (39), 259 (89), 242 (18), 203 (17), 202 (16), 201 (61),  
183 (58), 165 (100), 150 (20), 148 (25), 138 (24), 137 (61),  
122 (73), 121 (31), 111 (47), 101 (23), 96 (16), 75 (16), 44  
(17), 43 (29)

Compound 90. (Rt = 7.32min), m/z (rel. int.) 235 (M+,9), 219  
20 (16), 218 (100), 217 (42), 206 (17), 205 (9), 204 (7), 203  
(21), 202 (8), 193 (12), 192 (71), 191 (62), 190 (9), 189  
(19), 185 (13), 171 (14), 159 (9), 147 (14), 146 (16), 134  
(10), 133 (17), 121 (14), 109 (11), 101 (8), 97 (17), 45  
(15)

25 Compound 91. (Rt = 10.67 min), m/z (rel. int.) 329 (M+,6),  
301 (20), 300 (81), 167 (18), 166 (6), 165 (18), 152 (10),  
132 (5), 120 (45), 119 (21), 118 (11), 117 (9), 115 (11),  
106 (6), 105 (5), 104 (12), 103 (5), 92 (8), 91 (100), 77  
(10), 41 (6)

30 Compound 92. (Rt = 10.37min), m/z (rel. int.) 337 (M+,30),

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338 (7), 204 (7), 203 (7), 201 (7), 183 (10), 133 (6), 121 (8), 120 (70), 106 (6), 92 (9), 91 (100)

Compound 93. (Rt = 10.25 min), m/z (rel. int.) 351 (M+,28), 352 (7), 337 (9), 336 (39), 203 (10), 201 (11), 183 (17),  
5 135 (6), 134 (20), 133 (6), 132 (6), 120 (11), 118 (5), 109 (18), 106 (12), 105 (100), 104 (13), 103 (8), 91 (14), 79 (11), 77 (12)

Compound 94. (Rt = 10.48 min), m/z (rel. int.) 365 (M+,2), 337 (25), 336 (100), 203 (8), 201 (8), 183 (14), 133 (5),  
10 132 (6), 120 (14), 119 (13), 118 (9), 115 (5), 109 (20), 106 (5), 104 (10), 91 (52)

Compound 95. (Rt = 6.68min), m/z (rel. int.) 283 (M+,59), 284 (11), 267 (11), 266 (71), 265 (19), 251 (24), 250 (9), 241 (14), 240 (100), 239 (48), 237 (30), 232 (10), 220 (17),  
15 219 (65), 199 (9), 152 (12), 151 (18), 142 (20), 140 (13), 139 (20), 127 (22), 119 (24), 114 (12), 101 (10), 63 (10), 44 (9)

Compound 96. (Rt = 6.93 min), m/z (rel. int.) 265 (M+,46), 249 (16), 248 (100), 247 (34), 233 (27), 232 (11), 223 (9),  
20 222 (65), 221 (39), 220 (10), 219 (36), 202 (14), 201 (54), 152 (15), 151 (14), 133 (9), 124 (12), 119 (9), 109 (9), 101 (14), 75 (9)

Compound 97. (Rt = 8.10 min), m/z (rel. int.) 241 (M+,101), 242 (18), 224 (50), 223 (19), 210 (11), 209 (37), 197 (12),  
25 196 (10), 195 (55), 194 (16), 193 (60), 181 (29), 178 (20), 167 (38), 166 (16), 165 (52), 153 (12), 152 (36), 136 (27), 133 (12), 132 (14), 116 (12), 115 (25), 103 (13), 91 (100), 77 (18)

Compound 98. (Rt = 6.69 min), m/z (rel. int.) 232 (M+,3),  
30 204 (11), 203 (37), 202 (30), 201 (100), 188 (9), 184 (14), 183 (84), 182 (10), 181 (15), 170 (9), 109 (17), 107 (10),

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83 (10), 75 (8), 57 (7)

Compound 99. (Rt = 6.75 min), m/z (rel. int.) 233 (M+,2),  
204 (12), 203 (68), 202 (26), 201 (100), 200 (6), 188 (9),  
184 (13), 183 (86), 182 (8), 181 (14), 170 (9), 133 (6), 109  
5 (15), 107 (11), 83 (11), 81 (7), 75 (7), 57 (9)

Compound 100. (Rt = 7.66 min), m/z (rel. int.) 261 (M+,150),  
262 (29), 217 (11), 216 (70), 215 (28), 214 (11), 203 (30),  
202 (31), 201 (100), 196 (10), 184 (15), 183 (90), 181 (11),  
133 (20), 124 (12), 122 (20), 109 (39), 101 (14), 83 (10),  
10 75 (10), 45 (43)

Compound 101. (Rt = 7.72 min), m/z (rel. int.) 245 (M+,20),  
229 (16), 228 (100), 227 (36), 213 (21), 211 (22), 202 (57),  
201 (30), 199 (21), 183 (50), 181 (14), 171 (15), 170 (26),  
165 (12), 152 (21), 134 (19), 133 (35), 122 (28), 120 (19),  
15 120 (13), 119 (12), 109 (20), 107 (20), 106 (18), 101 (15),  
94 (15), 91 (20), 77 (18), 74 (15), 65 (20), 63 (14), 55  
(14), 51 (15), 44 (27), 43 (17), 42 (14)

Compound 102. (Rt = 8.33 min), m/z (rel. int.) 273 (M+,19),  
204 (16), 203 (16), 201 (15), 183 (18), 177 (9), 133 (8),  
20 109 (13), 70 (41), 69 (100), 68 (20), 43 (25), 42 (5), 41  
(5)

Compound 103. (Rt = 8.59 min), m/z (rel. int.) 245 (M+,118),  
246 (20), 229 (15), 228 (100), 227 (85), 213 (27), 211 (23),  
209 (15), 207 (12), 202 (19), 201 (32), 200 (17), 199 (84),  
25 196 (10), 183 (38), 181 (15), 171 (13), 170 (23), 152 (19),  
151 (15), 150 (10), 134 (18), 133 (32), 131 (12), 122 (36),  
119 (15), 109 (24), 107 (10), 106 (12), 91 (19), 77 (12)

Compound 104. (Rt = 7.72 min), m/z (rel. int.) 261 (M+,94),  
262 (17), 217 (15), 216 (92), 215 (18), 204 (12), 203 (86),  
30 202 (25), 201 (100), 184 (10), 183 (69), 148 (12), 133 (13),  
122 (8), 109 (26), 101 (9), 83 (8), 45 (33)



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Compound 105. (Rt = 10.24 min), m/z (rel. int.) 351 (M+,7),  
201 (5), 183 (7), 135 (9), 134 (79), 133 (4), 109 (5), 92  
(8), 91 (100), 65 (8), 42 (7)

Compound 106. (Rt = 7.52 min), m/z (rel. int.) 259 (M+,77),  
5 260 (14), 258 (31), 244 (30), 228 (13), 227 (28), 214 (14),  
201 (24), 165 (12), 164 (100), 162 (29), 133 (56), 109 (44),  
75 (13), 44 (80), 42 (56)

Compound 107. (Rt = 7.45 min), m/z (rel. int.) 227 (M+,101),  
228 (16), 226 (100), 211 (22), 210 (68), 209 (49), 207 (13),  
10 196 (22), 184 (15), 183 (62), 150 (50), 148 (31), 133 (44),  
132 (53), 130 (45), 117 (15), 115 (29), 106 (14), 77 (18),  
75 (13), 51 (14)

Compound 108. (Rt = 7.46 min), m/z (rel. int.) 243 (M+,34),  
244 (6), 212 (6), 211 (9), 197 (6), 186 (12), 185 (10), 184  
15 (5), 183 (19), 165 (15), 133 (6), 120 (6), 103 (5), 77 (6),  
44 (100), 42 (6)

Compound 109. (Rt = 8.68 min), m/z (rel. int.) 285 (M+,110),  
286 (22), 284 (27), 256 (16), 228 (37), 227 (27), 225 (10),  
220 (11), 207 (15), 201 (27), 191 (14), 190 (100), 163 (11),  
20 162 (85), 161 (10), 147 (11), 146 (11), 133 (32), 109 (20),  
83 (12), 82 (36)

Compound 110. (Rt = 8.66 min), m/z (rel. int.) 285 (M+,91),  
286 (16), 284 (100), 243 (16), 227 (26), 225 (11), 221 (10),  
220 (17), 214 (12), 207 (15), 201 (23), 147 (25), 146 (16),  
25 133 (17), 109 (20), 42 (15)

Compound 111. (Rt = 8.81 min), m/z (rel. int.) 287 (M+,29),  
214 (9), 204 (15), 203 (18), 202 (9), 201 (34), 183 (42),  
135 (9), 133 (28), 109 (28), 84 (47), 83 (100), 82 (19), 75  
(8), 70 (16), 68 (13), 57 (18), 56 (28), 44 (16), 43 (25),  
30 42 (14)

Compound 112. (Rt = 8.85 min), m/z (rel. int.) 287 (M+,141),

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288 (29), 286 (22), 202 (21), 201 (62), 183 (64), 133 (23),  
109 (27), 84 (100), 83 (18), 82 (31), 57 (14), 56 (58), 55  
(53), 43 (14), 42 (35)

Compound 113. (Rt = 9.08 min), m/z (rel. int.) 251 (M+, 27),  
5 180 (38), 179 (36), 178 (39), 174 (15), 173 (100), 166 (11),  
165 (53), 158 (12), 152 (10), 132 (9), 115 (28), 91 (31), 82  
(18), 77 (16), 56 (45), 51 (9), 43 (23)

Compound 114. (Rt = 8.71 min), m/z (rel. int.) 237 (M+, 197),  
238 (37), 236 (67), 193 (15), 179 (30), 178 (40), 165 (41),  
10 159 (43), 158 (26), 132 (24), 130 (16), 116 (17), 115 (37),  
106 (21), 103 (34), 91 (50), 77 (48), 57 (68), 56 (100), 51  
(32), 43 (50), 42 (34)

Compound 115. (Rt = 9.45 min), m/z (rel. int.) 271 (M+, 34),  
255 (12), 254 (67), 253 (14), 239 (23), 229 (16), 228 (100),  
15 227 (18), 224 (16), 223 (68), 213 (9), 212 (10), 211 (10),  
197 (34), 196 (17), 195 (11), 181 (18), 169 (10), 165 (22),  
153 (19), 152 (27), 146 (16), 145 (13), 141 (12), 139 (10),  
136 (22), 134 (11), 133 (41), 122 (16), 121 (31), 115 (30),  
91 (18), 77 (15), 65 (11), 63 (10), 44 (10)

20 Compound 116. (Rt = 9.50 min), m/z (rel. int.) 269 (M+, 41),  
268 (32), 254 (8), 253 (21), 252 (100), 251 (14), 238 (23),  
237 (18), 221 (10), 209 (9), 178 (8), 165 (19), 162 (22),  
160 (19), 152 (18), 147 (11), 146 (8), 145 (18), 139 (9),  
130 (11), 115 (10)

25 Compound 117. (Rt = 7.64 min), m/z (rel. int.) 212 (M+, 13),  
183 (16), 182 (100), 180 (7), 167 (7), 152 (3), 104 (27), 91  
(7), 78 (4), 77 (41), 51 (13)

Compound 118. (Rt = 7.46 min), m/z (rel. int.) 245 (M+, 4),  
153 (8), 152 (43), 150 (9), 135 (6), 133 (10), 124 (5), 123  
30 (36), 122 (38), 121 (17), 109 (16), 101 (14), 96 (24), 95  
(16), 94 (100), 93 (7), 83 (7), 77 (21), 75 (11), 66 (15),

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65 (30), 63 (10), 51 (14), 50 (6)

Compound 119. (Rt = 7.39 min), m/z (rel. int.) 263 (M+,7),  
171 (14), 170 (14), 152 (74), 151 (13), 150 (20), 141 (55),  
135 (10), 133 (23), 123 (20), 122 (100), 121 (49), 120 (11),  
5 113 (9), 112 (92), 111 (9), 109 (41), 107 (12), 103 (13),  
102 (11), 101 (40), 97 (9), 96 (66), 95 (51), 94 (9), 84  
(28), 83 (88), 82 (8), 81 (16), 77 (14), 75 (54), 74 (10),  
70 (10), 69 (10), 64 (10), 63 (23), 57 (62), 56 (13), 51  
(15), 50 (12), 42 (8)

10 Compound 120. (Rt = 8.48 min), m/z (rel. int.) 279 (M+,4),  
159 (16), 157 (49), 153 (11), 152 (100), 150 (12), 133 (11),  
130 (27), 128 (73), 123 (12), 122 (57), 121 (23), 111 (10),  
109 (25), 101 (23), 99 (16), 96 (26), 95 (10), 83 (9), 75  
(28), 73 (10), 65 (12), 64 (11), 63 (22), 51 (9), 50 (8)

15 Compound 121. (Rt = 8.30 min), m/z (rel. int.) 275 (M+,2),  
152 (15), 125 (8), 124 (100), 122 (14), 121 (7), 109 (35),  
96 (7), 95 (10), 81 (14), 77 (9), 65 (7), 52 (11)

Compound 122. (Rt = 7.39 min), m/z (rel. int.) 263 (M+,1),  
170 (12), 152 (66), 151 (10), 150 (18), 141 (68), 135 (10),  
20 133 (19), 123 (16), 122 (76), 121 (39), 112 (100), 111 (18),  
109 (36), 107 (11), 103 (11), 102 (9), 101 (33), 96 (56), 95  
(32), 92 (11), 83 (96), 81 (13), 77 (13), 75 (43), 64 (25),  
63 (26), 57 (61), 56 (14), 51 (14), 50 (11)

Compound 123. (Rt = 5.88 min), m/z (rel. int.) 275 (M+,46),  
25 276 (9), 202 (8), 201 (30), 183 (28), 133 (8), 109 (9), 101  
(9), 71 (9), 59 (12), 58 (100), 44 (8), 42 (26)

Compound 124. (Rt = 7.05 min), m/z (rel. int.) 229 (M+,15),  
213 (15), 212 (89), 211 (13), 198 (20), 197 (100), 196 (24),  
186 (12), 185 (21), 184 (29), 183 (87), 179 (7), 178 (8),  
30 177 (13), 176 (5), 171 (7), 170 (18), 169 (4), 166 (5), 165  
(20), 152 (5), 133 (7), 75 (4), 63 (4), 57 (9), 56 (4)

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- Compound 125. (Rt = 7.54 min), m/z (rel. int.) 225 (M+,57),  
226 (13), 209 (13), 208 (75), 193 (13), 180 (14), 179 (21),  
178 (20), 165 (22), 130 (34), 117 (59), 115 (28), 105 (18),  
104 (94), 103 (45), 91 (100), 78 (30), 77 (38), 65 (36), 63  
5 (13), 51 (20), 45 (17)
- Compound 126. (Rt = 7.81 min), m/z (rel. int.) 261 (M+,12),  
244 (31), 152 (27), 151 (17), 150 (9), 136 (11), 135 (100),  
133 (21), 122 (24), 115 (9), 110 (13), 109 (90), 107 (6), 96  
(7), 83 (27), 56 (7)
- 10 Compound 127. (Rt = 7.93 min), m/z (rel. int.) 225 (M+,23),  
208 (20), 207 (6), 193 (13), 181 (7), 180 (37), 179 (100),  
178 (36), 167 (9), 166 (12), 165 (36), 152 (9), 134 (30);  
130 (26), 129 (9), 117 (18), 115 (22), 104 (6), 91 (38), 77  
(7), 65 (7)
- 15 Compound 128. (Rt = 7.42 min), m/z (rel. int.) 211 (M+,83),  
212 (15), 194 (36), 193 (18), 182 (62), 181 (20), 180 (17),  
179 (53), 178 (60), 176 (11), 167 (57), 166 (44), 165 (100),  
152 (24), 120 (39), 116 (12), 115 (28), 104 (22), 103 (15),  
91 (46), 89 (16), 78 (10), 77 (20), 65 (15), 63 (12), 51  
20 (12)
- Compound 129. (Rt = 7.39 min), m/z (rel. int.) 229 (M+,104),  
230 (19), 212 (28), 211 (14), 201 (13), 200 (85), 199 (22),  
198 (14), 197 (50), 196 (58), 185 (73), 184 (45), 183 (100),  
179 (43), 178 (55), 177 (17), 176 (17), 170 (18), 165 (33),  
25 152 (12), 133 (22), 120 (57), 115 (17), 109 (44), 104 (23),  
103 (17), 91 (32), 89 (16), 83 (20), 78 (12), 77 (22), 63  
(16), 51 (13)
- Compound 130. (Rt = 7.38 min), m/z (rel. int.) 229 (M+,133),  
230 (24), 212 (27), 211 (14), 200 (54), 199 (17), 198 (16),  
30 197 (53), 196 (64), 185 (49), 184 (43), 183 (100), 179 (28),  
178 (29), 177 (14), 170 (19), 165 (26), 133 (22), 120 (35),

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115 (19), 109 (32), 104 (17), 103 (18), 91 (38), 89 (17), 83 (18), 77 (24), 63 (16)

Compound 131. (Rt = 7.40 min), m/z (rel. int.) 229 (M+, 146), 230 (26), 212 (48), 211 (23), 200 (51), 199 (17), 198 (16),  
5 197 (61), 196 (70), 185 (50), 184 (43), 183 (100), 179 (28), 178 (28), 170 (20), 165 (23), 133 (21), 120 (35), 115 (20), 109 (59), 104 (25), 103 (17), 91 (27), 89 (17), 83 (22), 77 (22)

Compound 132. (Rt = 7.03 min), m/z (rel. int.) 0 (M+, .0),  
10 185 (14), 184 (100), 183 (23), 181 (17), 165 (18), 155 (12), 153 (14), 152 (12), 120 (85), 119 (67), 115 (10), 106 (16) 91 (19), 89 (14), 78 (12), 77 (25), 51 (16)

Compound 133. (Rt = 7.09 min), m/z (rel. int.) 211 (M+, 13), 195 (16), 194 (100), 181 (27), 180 (70), 179 (31), 178 (28),  
15 166 (25), 165 (40), 152 (9), 120 (14), 119 (14), 118 (12), 115 (10), 104 (26), 103 (53), 102 (12), 91 (62), 89 (10), 78 (13), 77 (42), 65 (17), 51 (13)

Compound 134. (Rt = 7.45 min), m/z (rel. int.) 211 (M+, 14), 183 (15), 182 (100), 181 (14), 179 (13), 178 (18), 167 (27),  
20 166 (18), 165 (46), 152 (10), 115 (8), 104 (8), 103 (6), 91 (29), 89 (7), 78 (5), 77 (7), 65 (7)

Compound 135. (Rt = 8.60 min), m/z (rel. int.) 273 (M+, 34), 257 (14), 256 (76), 231 (16), 230 (100), 228 (18), 227 (57), 213 (14), 211 (37), 202 (30), 201 (40), 199 (26), 184 (13),  
25 183 (50), 181 (12), 171 (17), 170 (20), 152 (15), 150 (19), 134 (15), 133 (31), 122 (14), 121 (29), 109 (16), 107 (13), 106 (17), 91 (12), 65 (12)

Compound 136. (Rt = 9.26 min), m/z (rel. int.) 275 (M+, 44), 277 (15), 260 (28), 259 (19), 258 (81), 257 (13), 243 (15),  
30 234 (33), 233 (19), 232 (100), 231 (13), 229 (15), 227 (42), 224 (15), 223 (86), 208 (13), 197 (45), 196 (26), 195 (13),

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182 (14), 181 (33), 179 (11), 178 (18), 166 (22), 165 (60),  
164 (12), 163 (10), 153 (32), 152 (55), 151 (18), 149 (10),  
139 (11), 137 (17), 136 (19), 121 (13), 115 (25), 102 (11),  
91 (16), 77 (17)

5 Compound 137. (Rt = 7.42 min), m/z (rel. int.) 245 (M+,1),  
153 (8), 152 (7), 141 (64), 135 (10), 134 (100), 132 (11),  
117 (6), 115 (12), 112 (56), 105 (15), 104 (55), 103 (32),  
95 (8), 91 (16), 84 (8), 83 (15), 78 (24), 77 (24), 75 (9),  
65 (6), 63 (8), 57 (10), 51 (9)

10 Compound 138. (Rt = 9.24 min), m/z (rel. int.) 289 (M+,77),  
290 (16), 230 (20), 229 (21), 215 (15), 203 (22), 201 (32),  
183 (36), 134 (10), 133 (13), 124 (10), 121 (9), 109 (10),  
101 (10), 73 (100), 43 (23)

Compound 139. (Rt = 7.25 min), m/z (rel. int.) 245 (M+,92),  
15 246 (15), 244 (67), 229 (16), 228 (63), 227 (46), 225 (10),  
224 (15), 214 (13), 201 (39), 183 (13), 151 (13), 150 (100),  
149 (14), 148 (58), 135 (22), 133 (54), 124 (14), 122 (12),  
109 (18), 101 (15), 75 (13)

Compound 140a. (Rt = 8.64 min), m/z (rel. int.) 271 (M+,72),  
20 272 (14), 270 (37), 255 (21), 254 (100), 242 (19), 227 (14),  
226 (63), 225 (50), 199 (19), 197 (30), 196 (25), 183 (32),  
176 (27), 170 (20), 150 (44), 148 (34), 146 (14), 133 (32),  
131 (14), 121 (11)

Compound 140b. (Rt = 8.68 min), m/z (rel. int.) 271 (M+,57),  
25 272 (10), 270 (33), 255 (20), 254 (100), 242 (15), 227 (12),  
226 (54), 225 (40), 209 (8), 199 (14), 197 (22), 196 (19),  
183 (25), 176 (21), 170 (16), 150 (33), 148 (22), 146 (9),  
133 (20), 131 (10)

Compound 141. (Rt = 8.44 min), m/z (rel. int.) 257 (M+,48),  
30 258 (8), 256 (36), 241 (21), 240 (100), 239 (19), 226 (22),  
225 (20), 209 (11), 197 (14), 196 (18), 183 (25), 170 (16),

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162 (19), 160 (10), 150 (28), 148 (26), 147 (9), 146 (8),  
145 (13), 133 (20), 130 (8), 121 (10)

Compound 142. ( $R_t$  = 8.47 min), m/z (rel. int.) 273 ( $M^+$ , 14),  
217 (5), 216 (31), 215 (5), 183 (8), 170 (4), 150 (5), 121

5 (4), 58 (5), 45 (5), 44 (100)

Compound 143. ( $R_t$  = 9.39 min), m/z (rel. int.) 273 ( $M^+$ , 47),  
275 (16), 274 (19), 272 (36), 258 (39), 257 (26), 256 (100),  
255 (17), 242 (25), 241 (15), 221 (23), 178 (25), 177 (11),  
176 (14), 168 (14), 167 (11), 166 (54), 165 (34), 164 (34),  
10 163 (16), 162 (45), 160 (19), 152 (28), 151 (22), 149 (19),  
147 (18), 145 (24), 139 (11), 136 (15), 131 (15), 130 (35),  
121 (15), 115 (14), 111 (11), 103 (13), 102 (19), 89 (11),  
77 (16), 75 (14), 63 (16), 51 (12)

Compound 145. ( $R_t$  = 7.35 min), m/z (rel. int.) 277 ( $M^+$ , 7),  
15 122 (10), 109 (8), 96 (6), 95 (6), 83 (10), 75 (6), 63 (2),  
57 (7), 44 (100), 42 (9).

Compound 148. ( $R_t$  = 8.43 min), m/z (rel. int.) 261 ( $M^+$ , 3),  
170 (14), 169 (5), 168 (44), 153 (4), 151 (4), 140 (6), 139  
(4), 138 (15), 132 (6), 125 (7), 123 (40), 115 (6), 103  
20 (24), 102 (8), 101 (5), 95 (7), 94 (100), 89 (5), 77 (22),  
75 (6), 66 (8), 65 (16), 63 (7), 51 (10), 50 (4).

Compound 149. ( $R_t$  = 9.28 min), m/z (rel. int.) 295 ( $M^+$ , 4),  
170 (32), 169 (12), 168 (100), 166 (8), 159 (22), 157 (66),  
152 (11), 140 (16), 139 (11), 138 (41), 132 (11), 130 (32),  
25 129 (8), 128 (82), 127 (10), 125 (16), 115 (12), 111 (15),  
103 (55), 102 (18), 101 (15), 99 (19), 89 (10), 77 (26), 76  
(8), 75 (27), 73 (11), 65 (11), 64 (10), 63 (22), 51 (11).

Compound 150. ( $R_t$  = 8.32 min), m/z (rel. int.) 279 ( $M^+$ , 4),  
171 (9), 170 (37), 169 (13), 168 (100), 166 (8), 142 (8),  
30 141 (88), 140 (19), 139 (12), 138 (42), 132 (12), 130 (7),  
125 (16), 115 (12), 113 (10), 112 (89), 111 (11), 104 (8),

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103 (60), 102 (19), 101 (12), 95 (14), 89 (11), 84 (11), 83 (24), 77 (29), 76 (6), 75 (24), 63 (13), 57 (17), 51 (11).

Compound 151. (Rt = 7.68 min), m/z (rel. int.) 261 (M+, 62), 244 (8), 216 (79), 203 (65), 201 (82), 183 (100), 121 (50),

5 101 (40), 75 (35), 44 (52).

Compound 152. (Rt = 8.097 min), m/z (rel. int.) 42 (34), 43 (10), 44 (42), 56 (13), 57 (10), 58 (72), 71 (6), 72 (74), 73 (14), 74 (14), 75 (14), 86 (15), 95 (9), 96 (10), 100 (42), 101 (31), 114 (90), 115 (8), 120 (10), 121 (20), 122

10 (9), 123 (7), 138 (10), 149 (9), 164 (7), 170 (8), 181 (7), 183 (100), 184 (15), 188 (8), 194 (6), 195 (7), 196 (10), 201 (64), 202 (21), 203 (63), 204 (10), 214 (12), 215 (12), 216 (12), 317 (92), 318 (20).

Compound 153. (Rt = 7.88 min), m/z (rel. int.) 42 (7), 43

15 (8), 44 (32), 46 (16), 72 (24), 75 (11), 86 (21), 95 (8), 96 (9), 101 (20), 109 (14), 121 (30), 122 (14), 123 (6), 139 (6), 149 (10), 170 (6), 181 (6), 183 (59), 184 (9), 188 (6), 194 (11), 195 (7), 196 (10), 201 (51), 202 (17), 203 (56), 204 (8), 214 (10), 215 (18), 216 (52), 217 (13), 289 (100),  
20 290 (20).

Compound 154. (Rt = 7.74 min), m/z (rel. int.) 42 (16), 44 (23), 45 (35), 46 (15), 58 (20), 72 (59), 73 (17), 75 (12), 86 (23), 96 (9), 101 (18), 121 (22), 183 (52), 194 (9), 201 (44), 202 (15), 203 (41), 214 (9), 215 (11), 216 (20), 217

25 (10), 289 (100), 290 (20).

Compound 155. (Rt = 7.67 min), m/z (rel. int.) 58 (44), 75 (15), 95 (9), 96 (11), 101 (22), 109 (16), 121 (33), 122 (15), 125 (12), 149 (9), 183 (62), 184 (10), 196 (12), 201 (57), 202 (19), 203 (53), 214 (11), 215 (19), 217 (13), 275

30 (100), 276 (18).

Compound 156. (Rt = 8.93 min), m/z (rel. int.) 237 (M+, 11),



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220 (41), 219 (30), 219 (30), 206 (7), 205 (39), 204 (5),  
194 (28), 193 (100), 192 (21), 191 (31), 190 (9), 189 (17),  
179 (15), 178 (50), 177 (5), 176 (5), 165 (20), 152 (7), 128  
(5), 116 (7), 115 (39), 91 (11).

5 Compound 157. (Rt = 10.88 min), m/z (rel. int.) 343 (M+,6),  
300 (100), 167 (16), 166 (6), 166 (6), 165 (16), 152 (9),  
133 (8), 120 (28), 118 (8), 117 (6), 115 (8), 104 (11), 92  
(5), 91 (62), 77 (7).

Compound 158. (Rt = 10.74 min), m/z (rel. int.) 342 (M+, .0),  
10 300 (100), 167 (13), 166 (5), 165 (13), 152 (7), 120 (22),  
118 (6), 115 (6), 106 (3), 104 (7), 91 (31).

Compound 159. (Rt = 11.41 min), m/z (rel. int.) 363 (M+,13),  
336 (33), 335 (24), 334 (95), 182 (10), 181 (9), 168 (14),  
167 (40), 166 (18), 165 (36), 156 (27), 155 (15), 154 (85),  
15 153 (27), 152 (29), 140 (9), 139 (7), 138 (14), 127 (32),  
126 (9), 125 (100), 117 (19), 116 (7), 115 (24), 103 (11),  
91 (43), 77 (15), 72 (7), 41 (12).

Compound 160. (Rt = 11.48 min), m/z (rel. int.) 363 (M+,8),  
336 (35), 335 (25), 334 (100), 182 (5), 181 (11), 168 (9),  
20 167 (29), 166 (13), 165 (29), 156 (11), 155 (11), 154 (37),  
153 (26), 152 (23), 140 (8), 139 (6), 138 (12), 127 (26),  
126 (7), 125 (81), 125 (81), 117 (13), 115 (17), 103 (7), 91  
(26), 89 (5), 77 (9).

Compound 161. (Rt = 11.83 min), m/z (rel. int.) 408 (M+,4),  
25 407 (12), 381 (24), 380 (98), 379 (25), 378 (100), 200 (77),  
199 (31), 198 (87), 197 (24), 184 (17), 182 (15), 181 (16),  
171 (75), 169 (77), 168 (18), 167 (60), 166 (22), 165 (58),  
152 (32), 118 (27), 117 (47), 116 (13), 115 (37), 104 (13),  
103 (19), 91 (64), 90 (17), 77 (25).

30 Compound 162. (Rt = 12.02 min), m/z (rel. int.) 408 (M+,3),  
380 (100), 379 (25), 378 (99), 200 (40), 199 (32), 198 (48),

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197 (30), 184 (18), 182 (16), 181 (23), 171 (83), 169 (85),  
168 (16), 167 (49), 166 (18), 165 (50), 152 (28), 119 (11),  
118 (32), 117 (46), 116 (12), 115 (34), 104 (11), 103 (17),  
91 (63), 90 (16), 89 (10), 77 (23).

5 Compound 163. (Rt = 10.58 min), m/z (rel. int.) 347 (M+,14),  
318 (100), 181 (5), 168 (6), 167 (24), 166 (17), 165 (26),  
152 (16), 150 (6), 139 (8), 138 (66), 137 (23), 137 (23),  
136 (10), 124 (6), 122 (13), 117 (8), 115 (14), 110 (8), 109  
(100), 103 (6), 91 (22), 77 (7).

10 Compound 164. (Rt = 10.59 min), m/z (rel. int.) 347 (M+,14),  
318 (100), 181 (5), 178 (5), 168 (7), 167 (27), 166 (17),  
165 (28), 152 (16), 150 (6), 139 (8), 138 (70), 137 (18);  
136 (11), 122 (14), 117 (6), 115 (13), 110 (7), 109 (79),  
103 (6), 91 (20), 91 (20), 77 (6).

15 Compound 165. (Rt = 10.61 min), m/z (rel. int.) 347 (M+,8),  
318 (95), 181 (8), 167 (20), 166 (10), 165 (21), 152 (13),  
138 (34), 137 (27), 136 (11), 136 (11), 122 (14), 117 (6),  
115 (11), 110 (8), 109 (100), 91 (22), 77 (6).

Compound 166. (Rt = 11.62 min), m/z (rel. int.) 359 (M+,2),  
20 330 (100), 167 (13), 165 (14), 152 (8), 150 (6), 149 (38),  
148 (7), 135 (8), 134 (13), 122 (7), 122 (7), 121 (73), 117  
(6), 115 (8), 91 (23), 77 (7).

Compound 167. (Rt = 11.18 min), m/z (rel. int.) 359 (M+,4),  
330 (100), 136 (0), 121 (6).

25 Compound 168. (Rt = 10.86 min), m/z (rel. int.) 343 (M+,6),  
314 (100), 167 (16), 166 (6), 165 (16), 152 (9), 134 (17),  
133 (13), 132 (6), 118 (14), 117 (9), 115 (10), 106 (7), 106  
(7), 105 (59), 91 (20), 77 (6).

Compound 169. (Rt = 10.94 min), m/z (rel. int.) 343 (M+,4),  
30 314 (100), 167 (14), 166 (5), 165 (15), 152 (8), 134 (9),  
133 (16), 132 (7), 132 (7), 118 (14), 117 (8), 115 (9), 106

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(6), 105 (62), 91 (18), 77 (5).

Compound 170. (Rt = 12.52 min), m/z (rel. int.) 374 (M+,13),  
345 (50), 315 (5), 207 (12), 194 (8), 193 (16), 179 (5), 168  
(9), 167 (22), 166 (16), 165 (100), 164 (15), 164 (15), 152  
5 (12), 136 (45), 117 (13), 115 (11), 104 (6), 103 (6), 91  
(26), 90 (8), 77 (7).

Compound 171. (Rt = 11.16 min), m/z (rel. int.) 341 (M+,14),  
182 (8), 181 (53), 168 (6), 167 (18), 167 (18), 166 (8), 165  
(21), 152 (11), 144 (8), 132 (18), 131 (100), 129 (10), 128  
10 (5), 120 (12), 118 (5), 117 (9), 116 (10), 115 (15), 106  
(5), 104 (9), 103 (9), 91 (48), 77 (10).

Compound 172. (Rt = 8.53 min), m/z (rel. int.) 275 (M+,165),  
274 (95), 260 (18), 259 (24), 258 (87), 257 (28), 254 (17),  
244 (41), 243 (46), 242 (18), 233 (30), 214 (26), 201 (46),  
15 189 (18), 188 (36), 183 (27), 181 (22), 180 (100), 178 (24),  
165 (38), 163 (28), 154 (17), 150 (39), 149 (25), 148 (82),  
139 (58), 135 (20), 133 (35), 109 (20).

Compound 173. (Rt = 8.44 min), m/z (rel. int.) 277 (M+,11),  
260 (80), 259 (34), 245 (8), 241 (7), 234 (8), 233 (23), 230  
20 (19), 229 (100), 214 (9), 203 (12), 202 (17), 201 (25), 190  
(8), 189 (25), 188 (18), 183 (18), 171 (7), 170 (15), 165  
(14), 164 (7), 154 (7), 152 (7), 151 (8), 134 (12), 133  
(23), 121 (7), 109 (13), 101 (8).

Compound 174. (Rt = 8.49 min), m/z (rel. int.) 291 (M+,59),  
25 260 (27), 259 (17), 234 (18), 233 (14), 230 (10), 229 (55),  
203 (12), 202 (10), 201 (18), 189 (20), 188 (14), 183 (15),  
170 (12), 169 (6), 168 (13), 165 (14), 164 (8), 152 (8), 151  
(6), 138 (7), 137 (8), 134 (7), 133 (13), 109 (12), 101 (7),  
57 (6), 44 (100), 42 (6).

30 Compound 175. (Rt = 9.64 min), m/z (rel. int.) 303 (M+,8),  
123 (47), 109 (6), 96 (7), 95 (40), 85 (26), 84 (100), 82

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(7), 75 (9), 68 (4), 56 (25), 55 (29), 43 (9), 42 (16).

Compound 176. (Rt = 8.35 min), m/z (rel. int.) 277 (M+, 24), 245 (8), 220 (6), 219 (5), 183 (4), 171 (6), 170 (10), 151 (5), 138 (7), 109 (5), 57 (6), 44 (100), 42 (6).

5 Compound 177. (Rt = 7.83 min), m/z (rel. int.) 241 (M+, .1), 134 (30), 109 (8), 108 (100), 107 (16), 104 (17), 103 (9), 91 (12), 90 (4), 79 (10), 78 (14), 77 (24), 65 (8), 51 (9).

Compound 178. (Rt = 8.29 min), m/z (rel. int.) 257 (M+, .1), 134 (17), 125 (8), 124 (100), 109 (23), 104 (10), 103 (6),  
10 95 (4), 91 (5), 81 (9), 78 (7), 77 (11), 65 (7), 52 (9), 51 (6)

Compound 179. (Rt = 7.88 min), m/z (rel. int.) 255 (M+, 6), 148 (12), 115 (5), 108 (8), 107 (7), 104 (12), 103 (7), 91 (11), 79 (5), 78 (11), 77 (19), 65 (6), 51 (5), 44 (100), 42  
15 (8).

Compound 180. (Rt = 7.28 min), m/z (rel. int.) 295 (M+, 1), 183 (10), 162 (22), 145 (11), 143 (28), 135 (10), 134 (100), 133 (11), 132 (13), 117 (6), 115 (12), 114 (6), 113 (9), 112 (7), 105 (17), 104 (57), 103 (32), 102 (6), 95 (7), 91 (18),  
20 89 (5), 83 (8), 79 (6), 78 (28), 77 (28), 75 (6), 65 (8), 63 (11), 51 (11).

Compound 181. (Rt = 7.7 min), m/z (rel. int.) 259 (M+, 3), 137 (16), 135 (5), 122 (15), 121 (6), 109 (15), 108 (100), 107 (18), 96 (7), 91 (5), 79 (7), 78 (5), 77 (17), 65 (5),  
25 51 (5).

Compound 182. (Rt = 8.00 min), m/z (rel. int.) 225 (M+, 2), 208 (51), 207 (40), 182 (14), 181 (100), 165 (7), 152 (24), 151 (8), 74 (2).

Compound 183. (Rt = 8.98 min), m/z (rel. int.) 241 (M+, 7),  
30 224 (33), 223 (46), 199 (6), 198 (15), 197 (100), 178 (6), 165 (28), 152 (13), 150 (2).

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Compound 184. (Rt = 8.90 min), m/z (rel. int.) 235 (M+,3),  
218 (30), 217 (13), 203 (8), 202 (9), 193 (10), 192 (67),  
191 (100), 190 (11), 189 (29), 178 (7), 165 (18), 152 (3).

Compound 185. (Rt = 7.37 min), m/z (rel. int.) 245 (M+, .1),  
5 152 (8), 141 (61), 135 (10), 134 (100), 132 (11), 115 (14),  
112 (64), 105 (19), 104 (71), 103 (45), 102 (8), 95 (13), 91  
(24), 89 (8), 84 (12), 83 (28), 79 (10), 78 (42), 77 (44),  
75 (16), 65 (12), 64 (7), 63 (16), 57 (24), 56 (7), 52 (7),  
51 (22), 50 (9).

10 Compound 186. (Rt = 7.31 min), m/z (rel. int.) 245 (M+, .1),  
152 (8), 141 (64), 135 (10), 134 (100), 132 (11), 117 (6),  
115 (13), 112 (38), 77 (40), 75 (14), 65 (11), 64 (6), 63  
(14), 57 (21), 52 (6), 51 (18), 50 (7).

Compound 187. (Rt = 8.64 min), m/z (rel. int.) 239 (M+, .0),  
15 221 (17), 220 (6), 207 (8), 196 (11), 195 (39), 194 (14),  
193 (11), 192 (38), 191 (7), 181 (6), 179 (21), 178 (100),  
168 (7), 167 (41), 166 (17), 165 (53), 164 (6), 153 (6), 152  
(26), 139 (6), 128 (7), 115 (18), 91 (6), 89 (6), 77 (6), 63  
(6), 51 (5), 44 (6).

20 **Example 30: Biological properties of synthesized  
arylalkylamines**

Compounds synthesized as described in Example 28 and  
Example 29 were tested for various biological properties  
detailed in the examples.

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Table 1

| Compound    | IC <sub>50</sub> (μM)<br>vs. NMDA <sup>a</sup> | IC <sub>50</sub> (μM)<br>vs. [ <sup>3</sup> H]MK-801 <sup>c</sup> |
|-------------|--|---|
| Compound 1  | 0.102 (7)                                      | 126 (4)   |
| Compound 2  | 0.192 (4)                                      | not tested  |
| Compound 3  | 0.003 (7)                                      | not tested  |
| Compound 4  | 0.184 (5)                                      | 89 (1)  |
| Compound 5  | 0.102 (1)<br>0.070 (3) <sup>b</sup>            | 15.2 (2)  |
| Compound 6  | 0.129 (1)                                      | > 100 (1)<br>(0% at 100 μM) <sup>d</sup>                          |
| Compound 7  | 0.163 (2)                                      | 129 (1)   |
| Compound 8  | 0.099 (2)                                      | 219 (1)   |
| Compound 9  | 1.2 (5)  | > 100 (2)<br>(10% at 100 μM) <sup>d</sup>                         |
| Compound 10 | 0.082 (2)                                      | ~ 80 (1)<br>(57% at 80 μM) <sup>d</sup>                           |
| Compound 11 | 4.0 (2)  | not tested  |
| Compound 12 | 6.0 (11)                                       | 98 (1)  |
| Compound 13 | not tested                                     | not tested  |
| Compound 14 | 8.8 (2)  | ~ 100 μM  |
| Compound 15 | 4.9 (3)  | ~ 100 μM  |
| Compound 16 | 5.1 (1)  | 28.8 (1)  |
| Compound 17 | 9.6 (1)  | 36.3 (1)  |
| Compound 18 | 5.1 (3)  | 34 (1)  |
| Compound 19 | 0.435 (11)                                     | 2.1 (5)   |
| Compound 20 | 0.070 (15)                                     | 0.252 (9)   |
| Compound 21 | 0.038 (3)                                      | 0.457 (2)   |
| Compound 22 | 0.145 (6)                                      | 3.45 (2)  |
| Compound 23 | 0.267 (3)                                      | 5.4 (1)   |

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|    |             |            |            |
|----|-------------|------------|------------|
|    | Compound 24 | 0.206 (6)  | 0.591 (6)  |
|    | Compound 25 | 0.279 (2)  | 0.871 (2)  |
|    | Compound 26 | 27 (2)     | 34 (2)     |
|    | Compound 27 | 0.071 (1)  | 0.180 (2)  |
| 5  | Compound 28 | 0.380 (1)  | 2.3 (3)    |
|    | Compound 29 | 1.9 (2)    | 5.8 (3)    |
|    | Compound 30 | 0.035 (2)  | 0.407 (2)  |
|    | Compound 31 | 0.052 (7)  | 1.3 (2)    |
|    | Compound 32 | 0.284 (5)  | 0.799 (3)  |
| 10 | Compound 33 | 0.060 (9)  | 0.181 (6)  |
|    | Compound 34 | 0.426 (6)  | 2.7 (3)    |
|    | Compound 35 | 6.2 (1)    | 25.1 (1)   |
|    | Compound 36 | not tested | not tested |
|    | Compound 37 | 0.944 (2)  | 11.1 (2)   |
| 15 | Compound 38 | 0.407 (2)  | 2.3 (2)    |
|    | Compound 39 | 0.251 (1)  | 2.9 (3)    |
|    | Compound 40 | 0.933 (1)  | 18.1 (3)   |
|    | Compound 41 | 0.724 (1)  | 14.0 (3)   |
|    | Compound 42 | not tested | not tested |
| 20 | Compound 43 | 0.232 (4)  | 7.5 (2)    |
|    | Compound 44 | not tested | not tested |
|    | Compound 45 | not tested | not tested |
|    | Compound 46 | 0.013 (3)  | 5.2 (2)    |
|    | Compound 47 | not tested | not tested |
| 25 | Compound 48 | not tested | not tested |
|    | Compound 49 | not tested | not tested |
|    | Compound 50 | 0.089 (6)  | 0.762 (4)  |

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|    |             |            |            |
|----|-------------|------------|------------|
| 5  | Compound 51 | 1.1 (4)    | 4.5 (2)    |
|    | Compound 52 | 0.102 (3)  | 0.380 (2)  |
|    | Compound 53 | 0.217 (3)  | 4.2 (2)    |
|    | Compound 54 | 0.036 (4)  | 0.046 (3)  |
|    | Compound 55 | 0.035 (3)  | 0.153 (2)  |
| 10 | Compound 56 | 0.218 (4)  | 0.955 (2)  |
|    | Compound 57 | 0.028 (4)  | 0.063 (2)  |
|    | Compound 58 | 0.028 (2)  | 0.203 (3)  |
|    | Compound 59 | 0.272 (2)  | 0.453 (3)  |
|    | Compound 60 | 0.416 (11) | 0.641 (9)  |
| 15 | Compound 61 | 0.134 (4)  | 0.324 (2)  |
|    | Compound 62 | 0.177 (5)  | 0.617 (1)  |
|    | Compound 63 | 0.093 (6)  | 0.245 (3)  |
|    | Compound 64 | 0.309 (3)  | 0.851 (2)  |
|    | Compound 65 | 0.167 (3)  | 2.0 (1)    |
| 20 | Compound 66 | 0.236 (4)  | 1.2 (2)    |
|    | Compound 67 | 10.95 (2)  | 2.9 (1)    |
|    | Compound 68 | 2.9 (1)    | not tested |
|    | Compound 69 | 0.224 (2)  | 0.366 (1)  |
|    | Compound 70 | 1.7 (1)    | not tested |
| 25 | Compound 71 | 6.35 (2)   | not tested |
|    | Compound 72 | 7.4 (1)    | not tested |
|    | Compound 73 | 12.6 (1)   | not tested |
|    | Compound 74 | 27.5 (1)   | not tested |
|    | Compound 75 | 0.94 (2)   | not tested |
|    | Compound 76 | 0.73 (2)   | not tested |
|    | Compound 77 | 5.5 (2)    | not tested |
|    | Compound 78 | 10.2 (1)   | not tested |



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|    |              |           |           |
|----|--------------|-----------|-----------|
|    | Compound 79  | 12.6 (4)  | 10.2 (2)  |
|    | Compound 80  | 28 (1)    | 182 (1)   |
|    | Compound 81  | 1.4 (1)   | 6.1 (2)   |
|    | Compound 82  | 0.106 (5) | 0.794 (1) |
| 5  | Compound 83  | 0.342 (4) | 0.794 (1) |
|    | Compound 84  | 7.9 (2)   | 23.4 (1)  |
|    | Compound 85  | 1.2 (3)   | 3.5 (1)   |
|    | Compound 86  | 1.2 (3)   | 6.0 (1)   |
|    | Compound 87  | 0.657 (4) | 3.0 (1)   |
| 10 | Compound 88  | 2.5 (3)   | 10.6 (2)  |
|    | Compound 89  | 0.240 (3) | 1.2 (2)   |
|    | Compound 90  | 0.270 (4) | 1.4 (2)   |
|    | Compound 91  | 0.162 (3) | 14.1 (2)  |
|    | Compound 92  | 1.3 (3)   | 20.2 (2)  |
| 15 | Compound 93  | 0.486 (3) | 26.9 (2)  |
|    | Compound 94  | 0.248 (4) | 22.6 (2)  |
|    | Compound 95  | 0.311 (3) | 3.0 (2)   |
|    | Compound 96  | 0.187 (5) | 1.1 (2)   |
|    | Compound 97  | 0.410 (3) | 2.6 (1)   |
| 20 | Compound 98  | 7.9 (1)   | 52.5 (2)  |
|    | Compound 99  | > 100 (1) | 105 (2)   |
|    | Compound 100 | 0.602 (2) | 3.2 (1)   |
|    | Compound 101 | 0.912 (2) | 2.0 (1)   |
|    | Compound 102 | 1.01 (2)  | 3.3 (1)   |
| 25 | Compound 103 | 0.380 (4) | 0.661 (2) |
|    | Compound 104 | 7.983 (3) | > 10 (1)  |
|    | Compound 105 | 1.03 (1)  | > 3 (1)   |
|    | Compound 106 | 0.767 (1) | 1.31 (1)  |

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|    |              |           |            |
|----|--------------|-----------|------------|
| 5  | Compound 107 | 2.67 (1)  | 3.83 (1)   |
|    | Compound 108 | 1.06 (1)  | 0.942 (1)  |
|    | Compound 109 | 1.95 (1)  | 1.08 (3)   |
|    | Compound 110 | 42.7 (1)  | 13.3 (1)   |
|    | Compound 111 | 0.645 (3) | 0.167 (2)  |
| 10 | Compound 112 | 28.0 (2)  | 21.0 (1)   |
|    | Compound 113 | 13.5 (1)  | not tested |
|    | Compound 114 | 3.4 (1)   | not tested |
|    | Compound 115 | 1.4 (1)   | 1.0 (1)    |
|    | Compound 116 | 3.6 (1)   | not tested |
| 15 | Compound 117 | 19.6 (2)  | 6.0 (2)    |
|    | Compound 118 | 0.409 (2) | 0.240 (3)  |
|    | Compound 119 | 0.115 (4) | 0.087 (3)  |
|    | Compound 120 | 0.101 (3) | 0.074 (3)  |
|    | Compound 121 | 0.656 (3) | 0.670 (3)  |
| 20 | Compound 122 | 0.209 (2) | 0.342 (2)  |
|    | Compound 123 | 9.6 (7)   | > 3 (2)    |
|    | Compound 124 | 3.5 (1)   | 14.3 (3)   |
|    | Compound 125 | 1.7 (1)   | 6.7 (2)    |
|    | Compound 126 | 0.398 (3) | 6.0 (1)    |
| 25 | Compound 127 | 1.2 (3)   | 17.5 (2)   |
|    | Compound 128 | 0.646 (4) | 5.5 (1)    |
|    | Compound 129 | 1.26 (2)  | not tested |
|    | Compound 130 | 0.851 (2) | not tested |
|    | Compound 131 | 1.23 (2)  | not tested |
|    | Compound 132 | 1.3 (1)   | 6.4 (1)    |
|    | Compound 133 | 0.760 (1) | 3.0 (1)    |
|    | Compound 134 | 2.5 (1)   | > 10 (1)   |

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|    |              |            |            |
|----|--------------|------------|------------|
| 5  | Compound 135 | 0.244 (2)  | 1.185 (2)  |
|    | Compound 136 | 0.139 (2)  | 0.706 (1)  |
|    | Compound 137 | 0.232 (3)  | 0.074 (2)  |
|    | Compound 138 | 107 (1)    | > 100 (1)  |
|    | Compound 139 | 1.97 (2)   | 5.6 (2)    |
| 10 | Compound 140 | 20.8 (1)   | not tested |
|    | Compound 141 | 4.26 (1)   | 8.97 (1)   |
|    | Compound 142 | 1.013 (3)  | 1.54 (2)   |
|    | Compound 143 | 2.82 (1)   | not tested |
|    | Compound 144 | not tested | not tested |
| 15 | Compound 145 | 0.098 (1)  | 0.626 (1)  |
|    | Compound 146 | 0.829 (3)  | 0.372 (1)  |
|    | Compound 147 | 0.894 (2)  | not tested |
|    | Compound 148 | 0.549 (2)  | 0.373 (2)  |
|    | Compound 149 | 0.085 (3)  | 0.150 (3)  |
| 20 | Compound 150 | 0.195 (2)  | 0.351 (2)  |
|    | Compound 151 | 54.9 (1)   | > 100 (1)  |
|    | Compound 152 | not tested | not tested |
|    | Compound 153 | not tested | not tested |
|    | Compound 154 | not tested | not tested |
| 25 | Compound 155 | not tested | not tested |
|    | Compound 156 | 0.069 (3)  | 0.090 (2)  |
|    | Compound 157 | 0.142 (2)  | 23.16 (2)  |
|    | Compound 158 | 0.351 (2)  | 39.64 (1)  |
|    | Compound 159 | 0.185 (2)  | 10.41 (1)  |
|    | Compound 160 | 7.35 (3)   | 48.94 (1)  |
|    | Compound 161 | 0.247 (2)  | 5.62 (1)   |
|    | Compound 162 | 1.138 (2)  | 76.41 (1)  |

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|    |              |            |            |
|----|--------------|------------|------------|
|    | Compound 163 | 0.326 (2)  | 10.34 (1)  |
|    | Compound 164 | 0.475 (2)  | 18.30 (1)  |
|    | Compound 165 | 0.337 (2)  | 171 (1)    |
|    | Compound 166 | 0.619 (2)  | 36.7 (1)   |
| 5  | Compound 167 | 0.080 (2)  | 14.5 (1)   |
|    | Compound 168 | 0.092 (2)  | 17.4 (1)   |
|    | Compound 169 | 0.298 (2)  | 26.7 (1)   |
|    | Compound 170 | 0.238 (2)  | 57.0 (1)   |
|    | Compound 171 | 0.310 (3)  | 39.6 (1)   |
| 10 | Compound 172 | 38.0 (1)   | 37.3 (1)   |
|    | Compound 173 | 22.9 (1)   | 24.1 (1)   |
|    | Compound 174 | not tested | 57.0 (1)   |
|    | Compound 175 | not tested | 5.1 (1)    |
|    | Compound 176 | not tested | 10.0 (1)   |
| 15 | Compound 177 | not tested | 0.754 (1)  |
|    | Compound 178 | not tested | 1.25 (1)   |
|    | Compound 179 | not tested | 1.67 (1)   |
|    | Compound 180 | <100 (1)   | <10 (1)    |
|    | Compound 181 | 0.081 (1)  | 0.632 (1)  |
| 20 | Compound 182 | 2.6 (1)    | 7.05 (1)   |
|    | Compound 183 | 0.676 (1)  | 5.01 (1)   |
|    | Compound 184 | 1.5 (1)    | 1.51 (1)   |
|    | Compound 185 | 0.646 (1)  | 0.639 (1)  |
|    | Compound 186 | 0.155 (1)  | 0.123 (1)  |
| 25 | Compound 187 | 1.78 (1)   | 2.01 (1)   |
|    | Compound 188 | not tested | not tested |
|    | Compound 189 | not tested | not tested |
|    | Compound 190 | not tested | not tested |

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|    |              |            |            |
|----|--------------|------------|------------|
|    | Compound 191 | not tested | not tested |
|    | Compound 192 | not tested | not tested |
|    | Compound 193 | not tested | not tested |
|    | Compound 194 | not tested | not tested |
| 5  | Compound 195 | not tested | not tested |
|    | Compound 196 | not tested | not tested |
|    | Compound 197 | not tested | not tested |
|    | Compound 198 | not tested | not tested |
|    | Compound 199 | not tested | not tested |
| 10 | Compound 200 | not tested | not tested |
|    | Compound 201 | not tested | not tested |
|    | Compound 202 | not tested | not tested |
|    | Compound 203 | not tested | not tested |
|    | Compound 204 | not tested | not tested |
| 15 | Compound 205 | not tested | not tested |
|    | Compound 206 | not tested | not tested |
|    | Compound 207 | not tested | not tested |
|    | Compound 208 | not tested | not tested |
|    | Compound 209 | not tested | not tested |
| 20 | Compound 210 | not tested | not tested |
|    | Compound 211 | not tested | not tested |
|    | Compound 212 | not tested | not tested |
|    | Compound 213 | not tested | not tested |
|    | Compound 214 | not tested | not tested |
| 25 | Compound 215 | not tested | not tested |

<sup>a</sup>: Inhibition of NMDA/glycine-induced increases in intracellular calcium in cultured rat cerebellar granule cells (RCGC's) (see Example 1). (# in parentheses

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indicates the number of experiments).

<sup>b</sup>:TFA salt.

<sup>c</sup>:Inhibition of [<sup>3</sup>H]MK-801 binding in rat cortical/  
hippocampal washed membrane preparations (see

5 Example 4).

<sup>d</sup>:IC<sub>50</sub> study incomplete. % inhibition at the stated  
concentration.

A comparison of the IC<sub>50</sub> values in the RCGC  
assay with the IC<sub>50</sub> values in the [<sup>3</sup>H]MK-801 binding  
10 assay (Table 1) illustrates that the arylalkylamines of  
the invention inhibit NMDA receptor activity by a  
mechanism different than that of binding to the MK-801  
binding site; the concentration of the compound that  
inhibits NMDA receptor function is several orders of  
15 magnitude less than the concentration that competes at  
the site labeled by [<sup>3</sup>H]MK-801. This is not the case,  
however, with the simplified arylalkylamines exemplified  
by Compounds 19 - 215. Such compounds bind to the site  
labeled by [<sup>3</sup>H]MK-801 at concentrations ranging  
20 approximately 1 to 400-fold higher than those which  
antagonize NMDA receptor-mediated function in the rat  
cerebellar granule cell assay.

Some of the simplified arylalkylamines  
disclosed have structural features similar to portions  
25 of other compounds which are utilized as, for example,  
anticholinergics, antiparkinsonians, antihistamines,  
antidepressants, calcium channel blockers, coronary  
vasodilators, opiate analgesics, and antiarrhythmics.  
However, when certain of these compounds were evaluated  
30 for NMDA receptor antagonist potency (Example 1), as can  
be seen in Table 2, none of the compounds tested, with

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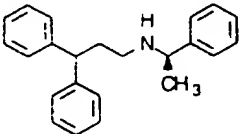
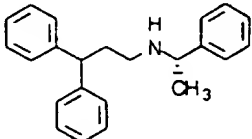
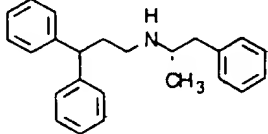
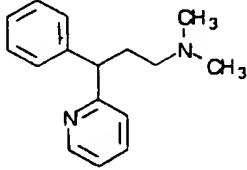
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the exception of (R)- and (S)-fendiline, nioxetine, and the Eli Lilly compound, had  $IC_{50}$  values less than 1  $\mu M$ .

These data are summarized in Table 2.

Table 2

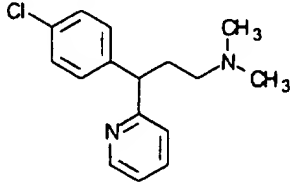
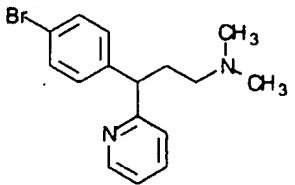
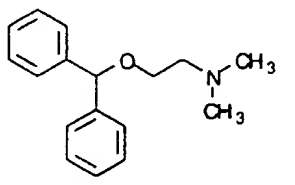
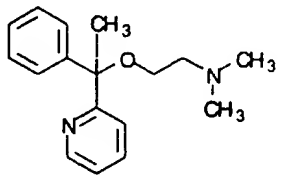
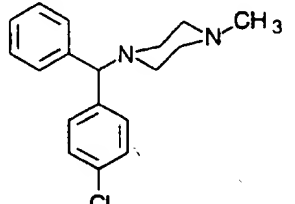
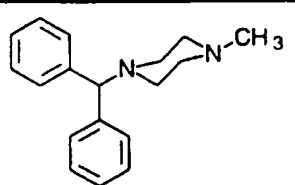
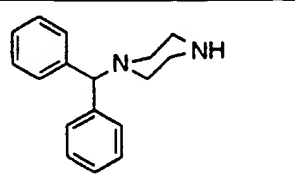
| Compound and Therapeutic Utility                                 | Structure   | $IC_{50}$ ( $\mu M$ ) vs. NMDA <sup>a</sup> |
|--|---|---|
| (R)-fendiline<br>(calcium channel blocker; coronary vasodilator) |    | 0.719                                       |
| (S)-fendiline<br>(calcium channel blocker; coronary vasodilator) |   | 0.686                                       |
| prenylamine<br>(calcium channel blocker; coronary vasodilator)   |  | ~10   |
| pheniramine<br>(antihistamine)                                   |  | 22  |

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Table 2

|    |   |   |      |
|----|---|---|------|
| 5  | chlorpheniramine<br>(antihistamine)               |    | >100 |
| 10 | brompheniramine<br>(antihistamine)                |    | 138  |
|    | diphenhydramine<br>(antihistamine)                |    | 26   |
| 15 | doxylamine<br>(antihistamine;<br>hypnotic)        |  | 62   |
|    | chlorcyclizine<br>(antihistamine)                 |  | -10  |
| 20 | cyclizine<br>(antiemetic)                         |  | 28   |
|    | nor-cyclizine<br>(pharmaceutical<br>intermediate) |  | 23   |

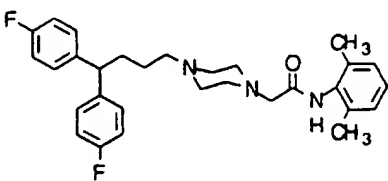
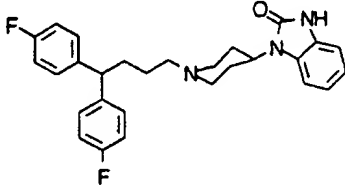
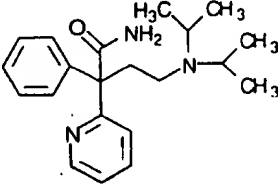
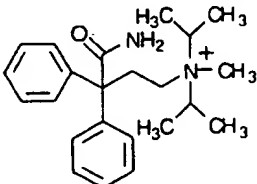
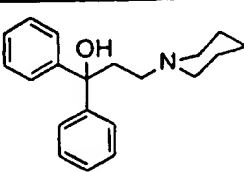
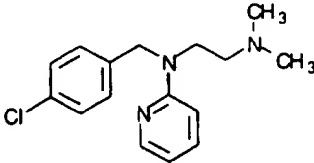
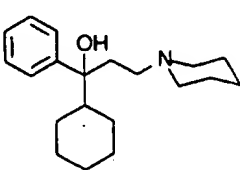


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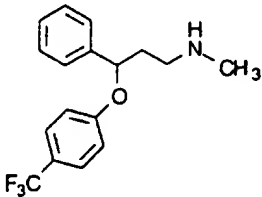
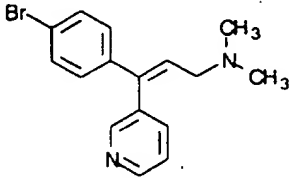
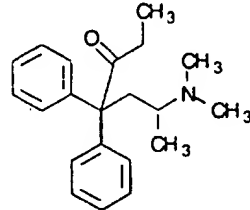
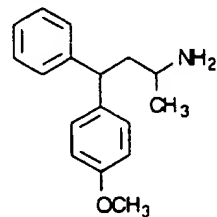
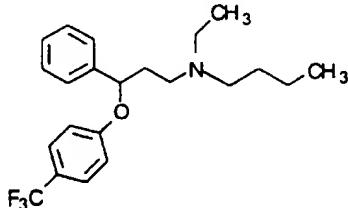
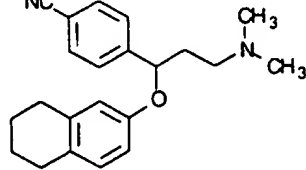
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|  |   |      |
|--|---|------|
| lidoflazine<br>(calcium channel<br>blocker; coronary<br>vasodilator) |   | >30  |
| pimozide<br>(antipsychotic)  |   | >10  |
| disopyramide<br>(antiarrhythmic)                                     |    | >100 |
| isopropamide<br>(anticholinergic)                                    |   | 87   |
| pridinol<br>(anticholinergic;<br>antiparkinsonian)                   |  | 10.7 |
| chloropyramine<br>(antihistamine)                                    |  | 76   |
| trihexyphenidyl<br>(anticholinergic;<br>antiparkinsonian)            |  | 5.13 |

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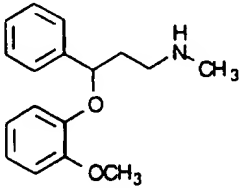
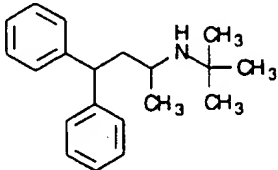
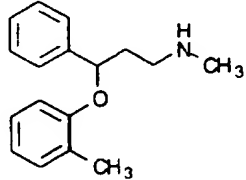
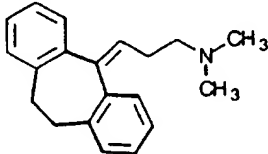
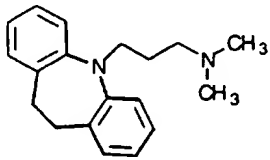
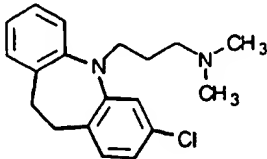
|  |  |            |
|--|--|------------|
| fluoxetine<br>(antidepressant)   |     | 3.4        |
| zimeldine<br>(antidepressant)  |     | $\geq 26$  |
| 5 methadone<br>(opiate analgesic)  |     | not tested |
| Astra compound <sup>b</sup><br>(antidepressant)  |   | > 30       |
| 10 Novo-Nordisk<br>compound <sup>c</sup><br>(calcium channel<br>blocker;<br>neuroprotectant) |  | not tested |
| Novo-Nordisk<br>compound <sup>d</sup><br>(calcium channel<br>blocker;<br>neuroprotectant)    |   | 28.8       |

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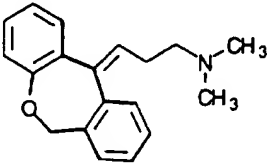
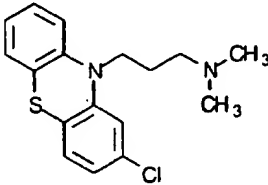
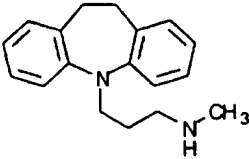
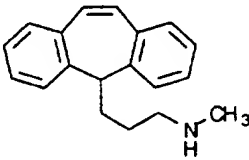
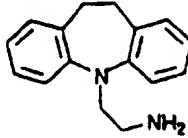
237

|  |  |              |
|--|--|--------------|
| nisoxetine<br>(monoamine uptake<br>inhibitor;<br>antidepressant)               |     | 0.894        |
| terodiline<br>(calcium channel<br>blocker;<br>anticholinergic;<br>vasodilator) |    | not tested   |
| tomoxetine<br>(monoamine uptake<br>inhibitor;<br>antidepressant)               |     | not tested - |
| amitriptyline<br>(serotonin uptake<br>inhibitor;<br>antidepressant)            |   | not tested   |
| imipramine<br>(serotonin uptake<br>inhibitor;<br>antidepressant)               |  | not tested   |
| clomipramine<br>(serotonin uptake<br>inhibitor;<br>antidepressant)             |  | not tested   |

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|    |  |   |            |
|----|--|---|------------|
| 5  | doxepine<br>(serotonin uptake<br>inhibitor;<br>antidepressant) |    | not tested |
| 10 | chlorpromazine<br>(dopamine<br>antagonist;<br>neuroleptic)     |    | not tested |
| 15 | desipramine<br>(antidepressant)                                |   | 2.3        |
|    | protriptyline<br>(antidepressant)                              |  | ≤ 10       |
| 20 | IRL Lilly Compound<br>(NMDA receptor<br>antagonist*)           |  | 0.609      |

a: Inhibition of NMDA/glycine-induced increases in intracellular calcium in cultured rat cerebellar granule cells (RCGC's) (see Example 1).

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- b: Disclosed as compound 2 in Table 4 in Marcusson et al., Inhibition of [<sup>3</sup>H]paroxetine binding by various serotonin uptake inhibitors: structure-activity relationships. *Europ. J. Pharmacol.* 215: 191-198, 1992.
- 5 c: Disclosed as compound 17 in Jakobsen et al., Aryloxy-phenylpropylamines and their calcium overload blocking compositions and methods of use. U.S. Patent No. 5,310,756, May 10, 1994.
- d: Disclosed as compound 25 in Jakobsen et al.,
- 10 Aryloxy-phenylpropylamines and their calcium overload blocking compositions and methods of use. U.S. Patent No. 5,310,756, May 10, 1994.
- e: Disclosed as Compound 1 in McQuaid et al., Inhibition of [<sup>3</sup>H]-MK801 binding and protection against NMDA-induced
- 15 lethality in mice by a series of imipramine analogs *Res. Comm. in Pathol. and Pharm.* 77:171-178, 1992.

Structure-activity relationship studies were initiated using Compound 19 as the lead structure. An examination of the side chain demonstrated that the

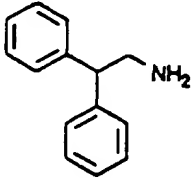
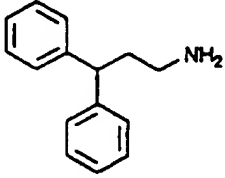
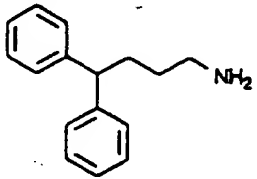
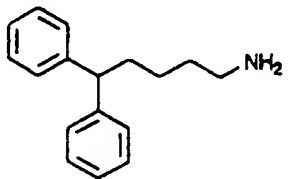
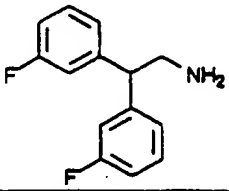
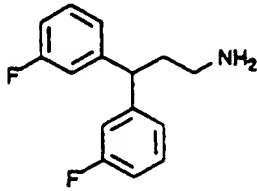
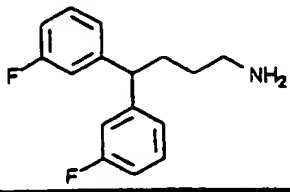
20 propyl side chain was optimal for NMDA receptor antagonist potency (Table 3). This finding was verified using Compound 20 as the lead structure (Table 3).

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Table 3

| Compound   | Structure  | IC <sub>50</sub><br>( $\mu$ M) vs.<br>NMDA* |
|--|--|---|
| 2,2-diphenylethylamine                                 |    | 24.5  |
| 3,3-diphenylpropylamine<br>(Compound 19)               |    | 0.435                                       |
| 4,4-diphenylbutylamine<br>(Compound 70)                |   | 1.7   |
| 5,5-diphenylpentylamine<br>(Compound 71)               |  | 6.4   |
| 2,2-bis(3-fluorophenyl)-1-ethylamine<br>(Compound 98)  |  | 7.9   |
| 3,3-bis(3-fluorophenyl)-1-propylamine<br>(Compound 20) |  | 0.070                                       |
| 4,4-bis(3-fluorophenyl)-1-butylamine<br>(Compound 100) |  | 0.602                                       |

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\*:Inhibition of NMDA/glycine-induced increases in intracellular calcium in cultured rat cerebellar granule cells (RCGC's) (see Example 1).

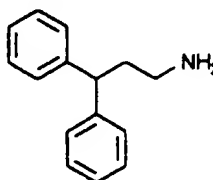
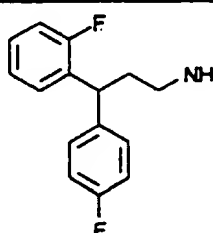
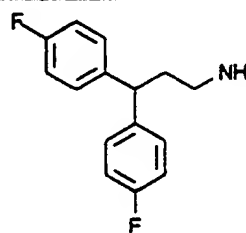
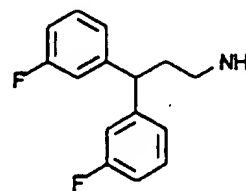
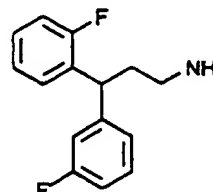
Further SAR studies examined the optimal  
5 pattern of phenyl ring substitution. Initial studies  
demonstrated that substitution of a halogen group  
(fluoro or chloro) at the *meta* position was optimal for  
NMDA receptor antagonist potency (Table 4). Increasing  
the number of fluoro substituents led to an apparent  
10 decrease in potency (Table 4).

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Table 4

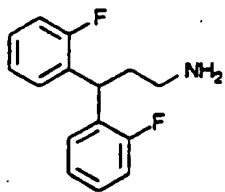
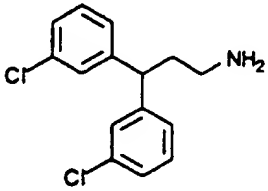
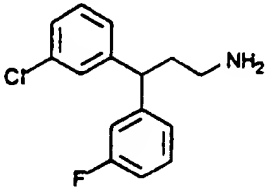
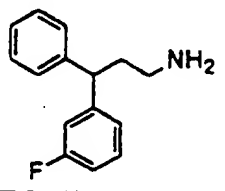
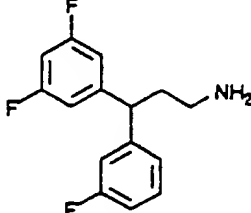
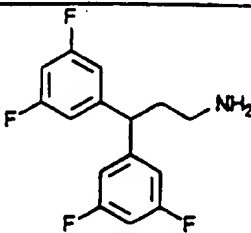
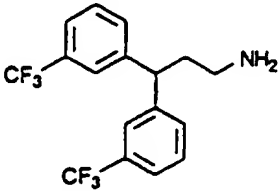
| Compound   | Structure  | IC <sub>50</sub><br>( $\mu$ M) vs.<br>NMDA <sup>a</sup> |
|--|--|---|
| 3,3-diphenyl-1-propylamine<br>(Compound 19)                          |    | 0.435   |
| 3-(2-fluorophenyl)-3-(4-fluorophenyl)-1-propylamine<br>(Compound 76) |    | 0.730   |
| 3,3-bis(4-fluorophenyl)-1-propylamine<br>(Compound 77)               |   | 5.5   |
| 3,3-bis(3-fluorophenyl)-1-propylamine<br>(Compound 20)               |  | 0.070   |
| 3-(2-fluorophenyl)-3-(3-fluorophenyl)-1-propylamine<br>(Compound 52) |  | 0.102   |



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|  |  |       |
|--|--|-------|
| 3,3-bis(2-fluorophenyl)-1-propylamine<br>(Compound 53)                   |    | 0.217 |
| 3,3-bis(3-chlorophenyl)-1-propylamine<br>(Compound 31)                   |    | 0.052 |
| 3-(3-fluorophenyl)-3-(3-chlorophenyl)-1-propylamine<br>(Compound 30)     |    | 0.035 |
| 3-(3-fluorophenyl)-3-phenyl-1-propylamine<br>(Compound 32)               |   | 0.284 |
| 3-(3,5-difluorophenyl)-3-(3-fluorophenyl)-1-propylamine<br>(Compound 96) |  | 0.187 |
| 3,3-bis(3,5-difluorophenyl)-1-propylamine<br>(Compound 97)               |  | 0.410 |
| 3,3-bis[3-(trifluoromethyl)phenyl]-1-propylamine<br>(Compound 78)        |  | 10.2  |

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<sup>a</sup>:Inhibition of NMDA/glycine-induced increases in intracellular calcium in cultured rat cerebellar granule cells (RCGC's) (see Example 1).

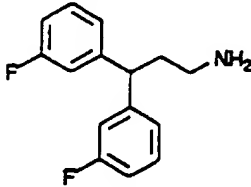
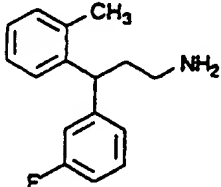
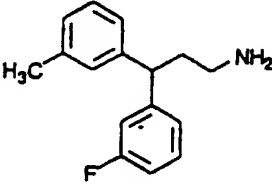
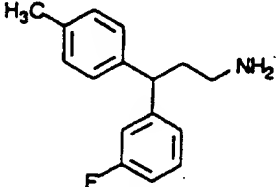
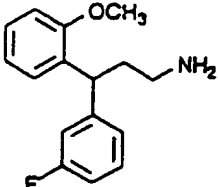
Replacement of one of the fluoro groups on one phenyl ring with a methyl, methoxy or hydroxy group led to no change or a decrease in the in vitro NMDA receptor antagonist potency. The ortho position was optimal for this methyl, methoxy or hydroxy group, and the rank order of potency for this substitution was methyl > methoxy > hydroxy (Table 5). Also illustrated in Table 5 are those compounds possessing the 3,3-bis(3-fluorophenyl) moiety with additional methyl or methoxy substitutions on the phenyl rings, often leading to an increase in NMDA receptor antagonist potency. Table 5 also illustrates those compounds possessing the 3,3-bis(2-methylphenyl) or 3,3-bis(2-methoxyphenyl) moiety in place of the 3,3-bis(3-fluorophenyl) moiety; these substitutions are acceptable, although a decrease in potency is noted.

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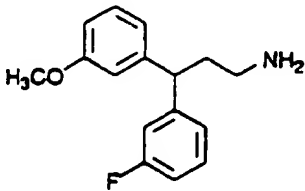
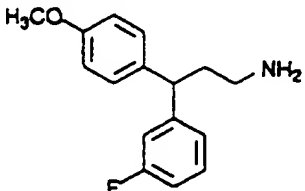
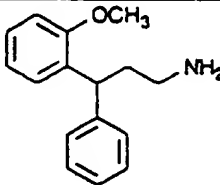
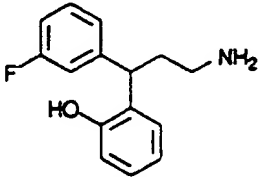
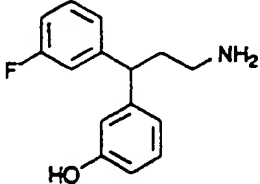
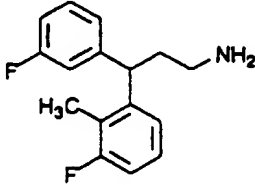
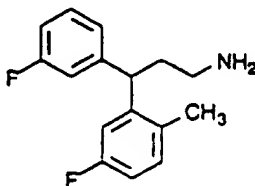
Table 5

| Compound  | Structure  | IC <sub>50</sub><br>( $\mu$ M) vs.<br>NMDA <sup>a</sup> |
|---|--|---|
| 3,3-bis(3-fluorophenyl)-1-propylamine<br>(Compound 20)                |    | 0.070   |
| 3-(3-fluorophenyl)-3-(2-methylphenyl)-1-propylamine<br>(Compound 27)  |    | 0.071   |
| 3-(3-fluorophenyl)-3-(3-methylphenyl)-1-propylamine<br>(Compound 28)  |   | 0.380   |
| 3-(3-fluorophenyl)-3-(4-methylphenyl)-1-propylamine<br>(Compound 29)  |  | 1.9   |
| 3-(3-fluorophenyl)-3-(2-methoxyphenyl)-1-propylamine<br>(Compound 24) |  | 0.206   |

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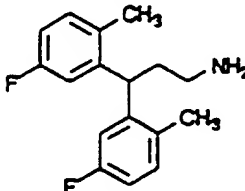
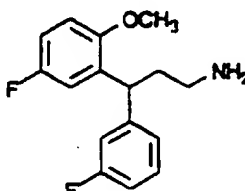
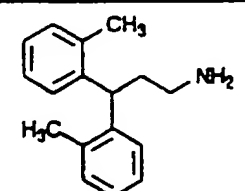
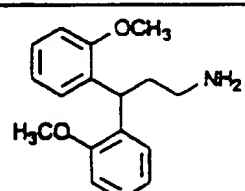
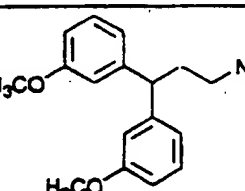
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|   |  |       |
|---|--|-------|
| 3-(3-fluorophenyl)-3-(3-methoxyphenyl)-1-propylamine<br>(Compound 25)         |    | 0.279 |
| 3-(3-fluorophenyl)-3-(4-methoxyphenyl)-1-propylamine<br>(Compound 26)         |    | 27    |
| 3-(2-methoxyphenyl)-3-phenyl-1-propylamine<br>(Compound 97)                   |    | 0.410 |
| 3-(2-hydroxyphenyl)-3-(3-fluorophenyl)-1-propylamine<br>(Compound 103)        |   | 0.380 |
| 3-(3-hydroxyphenyl)-3-(3-fluorophenyl)-1-propylamine<br>(Compound 101)        |  | 0.912 |
| 3-(3-fluorophenyl)-3-(2-methyl-3-fluorophenyl)-1-propylamine<br>(Compound 56) |  | 0.218 |
| 3-(3-fluorophenyl)-3-(3-fluoro-6-methylphenyl)-1-propylamine<br>(Compound 57) |  | 0.028 |

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|  |  |       |
|--|--|-------|
| 3,3-bis(3-fluoro-6-methylphenyl)-1-propylamine<br>(Compound 58)                |    | 0.028 |
| 3-(3-fluorophenyl)-3-(3-fluoro-6-methoxyphenyl)-1-propylamine<br>(Compound 61) |    | 0.134 |
| 3,3-bis(2-methylphenyl)-1-propylamine<br>(Compound 65)                         |   | 0.167 |
| 3,3-bis(2-methoxyphenyl)-1-propylamine<br>(Compound 62)                        |  | 0.177 |
| 3,3-bis(3-methoxyphenyl)-1-propylamine<br>(Compound 115)                       |  | 1.9   |

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<sup>a</sup>:Inhibition of NMDA/glycine-induced increases in intracellular calcium in cultured rat cerebellar granule cells (RCGC's) (see Example 1).

The next series of SAR experiments

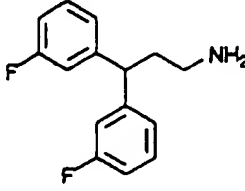
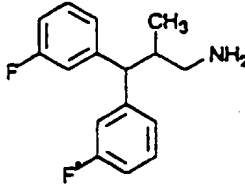
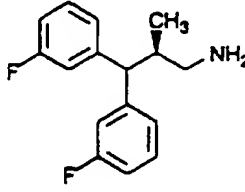
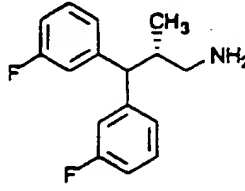
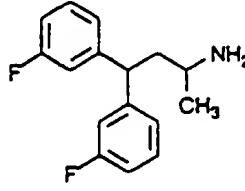
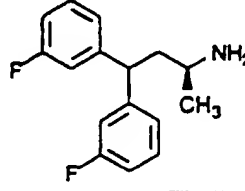
- 5 investigated the effect of alkyl chain substitutions (branching patterns) on NMDA receptor antagonist potency *in vitro*. The addition of a methyl group on either the  $\alpha$  or  $\beta$  carbon on the propyl side chain led to a decrease or no change in potency, respectively (Table 6).

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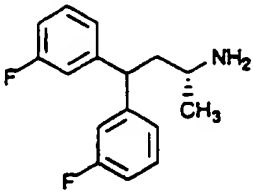
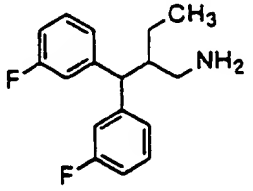
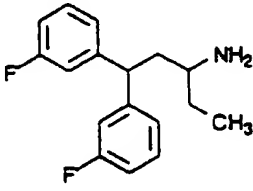
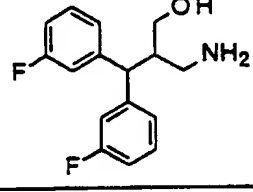
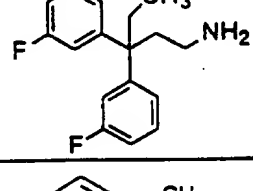
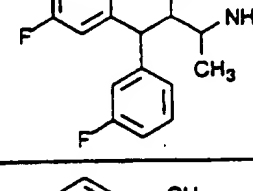
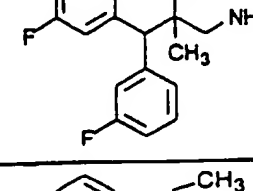
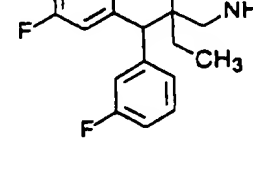
Table 6

| Compound  | Structure  | IC <sub>50</sub><br>( $\mu$ M) vs.<br>NMDA <sup>a</sup> |
|---|--|---|
| 3,3-bis(3-fluorophenyl)-1-propylamine<br>(Compound 20)          |    | 0.070   |
| 3,3-bis(3-fluorophenyl)-2-methyl-1-propylamine<br>(Compound 21) |    | 0.038   |
| 3,3-bis(3-fluorophenyl)-2-methyl-1-propylamine<br>(Compound 33) |   | 0.060   |
| 3,3-bis(3-fluorophenyl)-2-methyl-1-propylamine<br>(Compound 34) |  | 0.426   |
| 3,3-bis(3-fluorophenyl)-1-methyl-1-propylamine<br>(Compound 22) |  | 0.145   |
| 3,3-bis(3-fluorophenyl)-1-methyl-1-propylamine<br>(Compound 50) |  | 0.089   |

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|   |  |       |
|---|--|-------|
| 3,3-bis(3-fluorophenyl)-1-methyl-1-propylamine<br>(Compound 51)       |    | 1.1   |
| 3,3-bis(3-fluorophenyl)-2-ethyl-1-propylamine<br>(Compound 55)        |    | 0.035 |
| 3,3-bis(3-fluorophenyl)-1-ethyl-1-propylamine<br>(Compound 23)        |    | 2.67  |
| 3,3-bis(3-fluorophenyl)-2-hydroxyethyl-1-propylamine<br>(Compound 54) |   | 0.036 |
| 3,3-bis(3-fluorophenyl)-3-ethyl-1-propylamine<br>(Compound 82)        |  | 0.106 |
| 3,3-bis(3-fluorophenyl)-1,2-dimethyl-1-propylamine<br>(Compound 38)   |  | 0.407 |
| 3,3-bis(3-fluorophenyl)-2,2-dimethyl-1-propylamine<br>(Compound 41)   |  | 0.724 |
| 3,3-bis(3-fluorophenyl)-2,2-diethyl-1-propylamine<br>(Compound 80)    |  | 28    |



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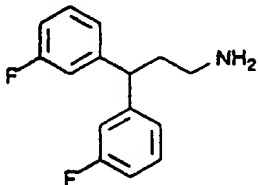
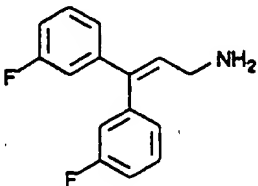
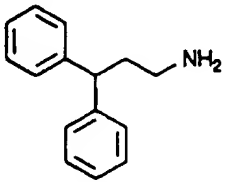
251

<sup>a</sup>: Inhibition of NMDA/glycine-induced increases in intracellular calcium in cultured rat cerebellar granule cells (RCGC's) (see Example 1).

The next series of SAR experiments

- 5 investigated the effect of incorporation of a double bond within the propyl chain on NMDA receptor antagonist potency *in vitro* (Table 7). As can be seen in Table 7, the incorporation of a double bond decreased potency in a consistent manner.

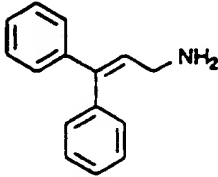
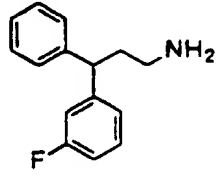
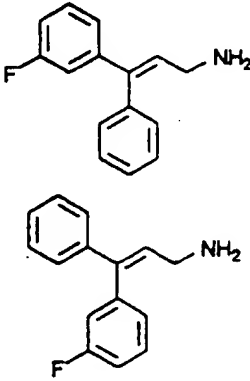
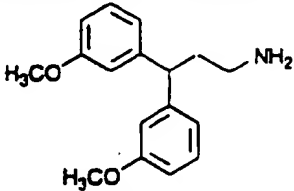
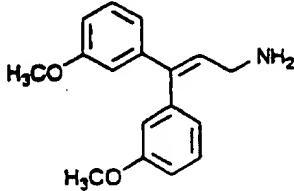
Table 7

| Compound   | Structure  | IC <sub>50</sub><br>( $\mu$ M) vs.<br>NMDA <sup>a</sup> |
|--|--|---|
| 3,3-bis(3-fluorophenyl)-1-propylamine<br>(Compound 20)       |  | 0.070   |
| 3,3-bis(3-fluorophenyl)-prop-2-ene-1-amine<br>(Compound 139) |  | 1.4   |
| 3,3-diphenyl-1-propylamine<br>(Compound 19)                  |  | 0.435   |

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|  |   |       |
|--|---|-------|
| 3,3-diphenyl-prop-2-ene-1-amine<br>(Compound 81)                 |                               | 1.4   |
| 3-(3-fluorophenyl)-3-phenyl-1-propylamine<br>(Compound 32)       |                               | 0.284 |
| 3-(3-fluorophenyl)-3-phenyl-prop-2-ene-1-amine<br>(Compound 107) | <br>(mixture of 2 compounds) | 2.67  |
| 3,3-bis(3-methoxyphenyl)-1-propylamine<br>(Compound 115)         |                             | 1.9   |
| 3,3-bis(3-methoxyphenyl)-prop-2-ene-1-amine<br>(Compound 116)    |                             | 4.47  |

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<sup>a</sup>: Inhibition of NMDA/glycine-induced increases in intracellular calcium in cultured rat cerebellar granule cells (RCGC's) (see Example 1).

The next series of SAR experiments

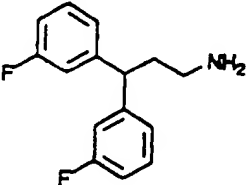
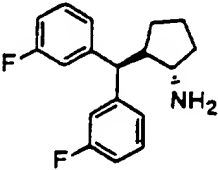
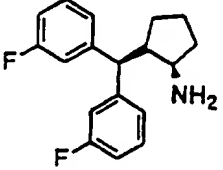
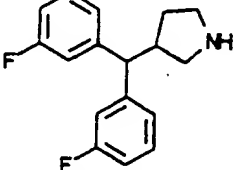
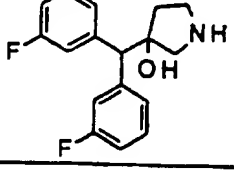
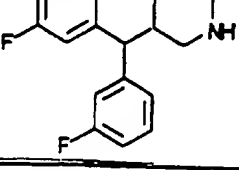
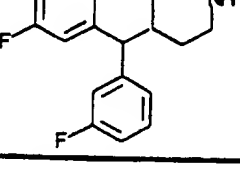
5 investigated the effect of incorporation of the propylamine chain into a ring structure on NMDA receptor antagonist potency *in vitro* (Table 8).

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Table 8

| Compound   | Structure  | IC <sub>50</sub><br>( $\mu$ M) vs.<br>NMDA <sup>a</sup> |
|--|--|---|
| 3,3-bis(3-fluorophenyl)-1-propylamine<br>(Compound 20) |    | 0.070   |
| Compound 63  |    | 0.093   |
| Compound 64  |   | 0.309   |
| Compound 102   |  | 1.01  |
| Compound 84  |  | 7.9   |
| Compound 111   |  | 0.790   |
| Compound 112   |  | 28.9  |

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\*:Inhibition of NMDA/glycine-induced increases in intracellular calcium in cultured rat cerebellar granule cells (RCGC's) (see Example 1).

The next series of SAR experiments

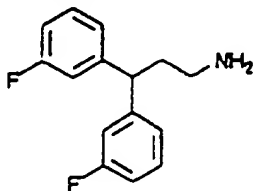
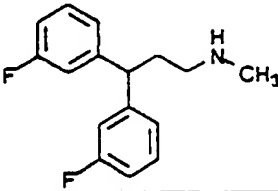
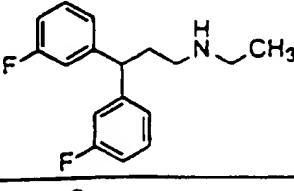
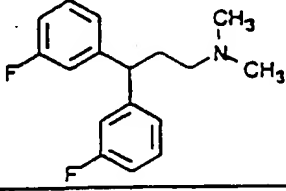
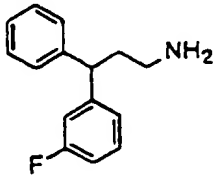
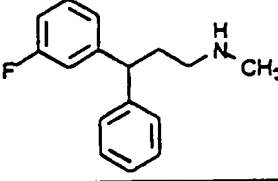
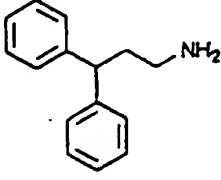
5 investigated the effect of simple alkyl substitution on the nitrogen on NMDA receptor antagonist potency *in vitro* (Table 9).

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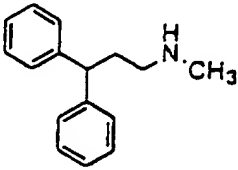
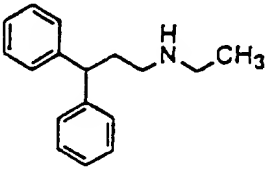
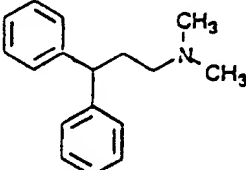
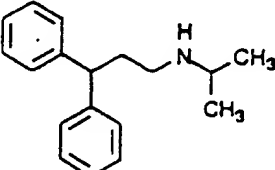
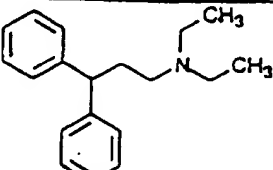
Table 9

| Compound   | Structure  | IC <sub>50</sub><br>( $\mu$ M) vs.<br>NMDA a |
|--|--|--|
| 3,3-bis(3-fluorophenyl)-1-propylamine<br>(Compound 20)               |    | 0.070  |
| N-methyl-3,3-bis(3-fluorophenyl)-1-propylamine<br>(Compound 60)      |    | 0.416  |
| N-ethyl-3,3-bis(3-fluorophenyl)-1-propylamine<br>(Compound 59)       |   | 0.272  |
| N,N-dimethyl-3,3-bis(3-fluorophenyl)-1-propylamine<br>(Compound 123) |  | 9.6  |
| 3-(3-fluorophenyl)-3-phenyl-1-propylamine<br>(Compound 32)           |  | 0.284  |
| N-methyl-3-(3-fluorophenyl)-3-phenyl-1-propylamine<br>(Compound 108) |  | 1.06   |
| 3,3-diphenylpropylamine<br>(Compound 19)                             |  | 0.435  |

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|   |  |       |
|---|--|-------|
| N-methyl-3,3-diphenylpropylamine<br>(Compound 67)     |    | 10.95 |
| N-ethyl-3,3-diphenylpropylamine<br>(Compound 68)      |    | 2.9   |
| N,N-dimethyl-3,3-diphenylpropylamine<br>(Compound 73) |    | 12.6  |
| N-isopropyl-3,3-diphenylpropylamine<br>(Compound 72)  |   | 7.4   |
| N,N-diethyl-3,3-diphenylpropylamine<br>(Compound 74)  |  | 27.5  |

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\*:Inhibition of NMDA/glycine-induced increases in intracellular calcium in cultured rat cerebellar granule cells (RCGC's) (see Example 1).

Certain simplified arylalkylamine compounds were selected for evaluation of activity in a battery of neurotransmitter receptor binding assays, and for activity against the L-type calcium channel and delayed rectifier potassium channel. The compounds were inactive (less than 50% inhibition at concentrations up to 10  $\mu$ M) in the following assays: nonselective  $\alpha$ 2 adrenergic receptor ([<sup>3</sup>H]RX 821002 binding in rat cortex), H1 histamine receptor ([<sup>3</sup>H]pyrilamine binding in bovine cerebellum), nonselective sigma receptor ([<sup>3</sup>H]DTG binding in guinea pig brain), nonselective opiate receptor ([<sup>3</sup>H]naloxone binding in rat forebrain), monoamine oxidase (MAO) activity, both MAO-A ([<sup>14</sup>C]serotonin metabolism in rat liver mitochondria) and MAO-B ([<sup>14</sup>C]phenylethylamine metabolism in rat liver mitochondria)

As can be seen in Table 10, activity was noted for several compounds at concentrations below 10  $\mu$ M in the following assays: L-type calcium channel, delayed rectifier potassium channel, central muscarinic cholinergic receptor binding, and monoamine (dopamine, norepinephrine, and serotonin) uptake binding assays. This profile of activity in the central muscarinic cholinergic receptor and monoamine uptake binding assays is not unexpected, given the chemical structures of our simplified arylalkylamines (refer to Table 2 above). With the exceptions, however, of the activity of Compound 19 in the serotonin uptake binding assay, the



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|    |                |       |               |               |                           |   |
|----|----------------|-------|---------------|---------------|---------------------------|---|
|    | Compound<br>34 | 0.426 | not<br>tested | ~ 10          | 25% at<br>0.199% at<br>10 | 60% at<br>0.1'99% at<br>10'10% at<br>0.1'64% at<br>10'12% at<br>0.1'79% at<br>10 <sup>n</sup>     |
|    | Compound<br>50 | 0.089 | not<br>tested | ~ 10          | 11% at<br>0.184% at<br>10 | 17% at<br>0.1'93% at<br>10'<br>10% at<br>0.1'78% at<br>10'75% at<br>0.1'97% at<br>10 <sup>n</sup> |
| 5  | Compound<br>46 | 0.013 | 0.676         | ~ 3           | 33% at<br>0.189% at<br>10 | 40% at<br>0.1'97% at<br>10'7% at<br>0.1'64% at<br>10'10% at<br>0.1'75% at<br>10 <sup>n</sup>      |
|    | Compound<br>63 | 0.093 | 1.9           | not<br>tested | 11% at<br>0.181% at<br>10 | 64% at<br>0.1'98% at<br>10'7% at<br>0.1'76% at<br>10'13% at<br>0.1'85% at<br>10 <sup>n</sup>      |
| 10 | Compound<br>64 | 0.309 | not<br>tested | not<br>tested | 11% at<br>0.183% at<br>10 | 50% at<br>0.1'99% at<br>10'<br>8% at<br>0.1'65% at<br>10'29% at<br>0.1'68% at<br>10 <sup>n</sup>  |

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activity of Compound 34 in the dopamine uptake binding assay, the activity of Compound 50 in the serotonin uptake binding assay, the activity of Compounds 63 and 64 in the dopamine uptake binding assay, and the activity of Compound 60 in the dopamine and serotonin uptake binding assays, the simplified arylalkylamine compounds were most potent at the NMDA receptor.

Table 10

| Compound             | IC <sub>50</sub> (μM)<br>vs. NMDA <sup>a</sup> | L-type<br>calcium<br>channel <sup>b</sup> | Delayed<br>rectifier<br>potassium<br>channel <sup>c</sup> | Central<br>muscarinic<br>cholinergic<br>receptor <sup>d</sup> | Monoamine<br>uptake<br>binding<br>assays <sup>e</sup>  |
|----------------------|--|---|---|---|--|
| 10<br>Compound<br>19 | 0.435  | 10.2                                      | 1-10  | 4% at<br>0.174% at<br>10                                      | 7% at<br>0.175% at<br>10 <sup>3</sup> % at<br>0.153% at<br>10 <sup>3</sup> 18% at<br>0.189% at<br>10 <sup>h</sup>          |
| Compound<br>20       | 0.070  | 2.2                                       | 1-10  | 8% at<br>0.190% at<br>10                                      | 6% at<br>0.181% at<br>10 <sup>3</sup> % at<br>5% at<br>0.158% at<br>10 <sup>3</sup> 28% at<br>0.194% at<br>10 <sup>h</sup> |
| 15<br>Compound<br>33 | 0.060  | 1.6                                       | > 10  | 42% at<br>0.199% at<br>10                                     | 23% at<br>0.186% at<br>10 <sup>3</sup> 2% at<br>0.154% at<br>10 <sup>3</sup> 14% at<br>0.189% at<br>10 <sup>h</sup>        |

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|   |                |       |               |               |                           |   |
|---|----------------|-------|---------------|---------------|---------------------------|---|
|   | Compound<br>58 | 0.028 | 1.6           | not<br>tested | 1% at<br>0.148% at<br>10  | 0% at<br>0.145% at<br>10 <sup>1</sup> % at<br>0.167% at<br>10 <sup>2</sup> 27% at<br>0.195% at<br>10 <sup>n</sup> |
|   | Compound<br>59 | 0.272 | not<br>tested | not<br>tested | 9% at<br>0.187% at<br>10  | 2% at<br>0.178% at<br>10 <sup>7</sup> % at<br>0.151% at<br>10 <sup>3</sup> 14% at<br>0.186% at<br>10 <sup>n</sup> |
| 5 | Compound<br>60 | 0.416 | 2.3           | not<br>tested | 13% at<br>0.193% at<br>10 | 0.914±16%<br>at 0.164%<br>at 10 <sup>9</sup><br>0.068 <sup>n</sup>  |

<sup>a</sup>: Inhibition of NMDA/glycine-induced increases in intracellular calcium in cultured rat cerebellar granule cells (RCGC's) (see Example 1).

10 <sup>b</sup>: Inhibition of KCl depolarization-induced increases in intracellular calcium in cultured rat cerebellar granule cells (RCGCs); estimated IC<sub>50</sub> value in  $\mu$ M.

<sup>c</sup>: Inhibition of delayed rectifier potassium channel in cultured N1E-115 neuroblastoma cells; estimated IC<sub>50</sub> value in  $\mu$ M.

<sup>d</sup>: Inhibition of the binding of [<sup>3</sup>H]quinuclidinylbenzilate (QNB) to rat cortical membranes; percent block at indicated concentration in  $\mu$ M.

<sup>e</sup>: Inhibition of the binding of [<sup>3</sup>H]WIN-35,428 to guinea pig striatal membranes (dopamine uptake binding assay), [<sup>3</sup>H]desipramine to rat cortical membranes (norepinephrine uptake binding assay), or [<sup>3</sup>H]citalopram to rat forebrain membranes (serotonin uptake binding assay); percent

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block at indicated concentration in  $\mu\text{M}$ , or  $\text{IC}_{50}$ , when available.

':dopamine uptake binding assay

':norepinephrine uptake binding assay

5   ':serotonin uptake binding assay

Advantageous properties of the arylalkylamine compounds of the present invention are illustrated by the fact that concentrations which suppress NMDA receptor-mediated synaptic transmission fail to inhibit

- 10 LTP. Furthermore, while compounds such as Compound 9, and 11 do produce a hypotensive response following systemic administration in rats, the hypotensive effect produced by these compounds is of a relatively short duration (approximately 30 min). Additionally,
- 15 Compounds 12 and 14 have no cardiovascular activity at doses up to  $37.3 \mu\text{moles/kg}$  i.v. and  $15 \mu\text{moles/kg}$  i.v., respectively.

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Table 11

| Compound       | Suppression of NMDA Receptor-Mediated Synaptic Transmission <sup>a</sup> | LTP Assay <sup>b</sup>  | Drop in Mean Arterial Blood Pressure <sup>c</sup>     |
|----------------|--|-------------------------|---|
| Compound 1     | 10 - 30 $\mu$ M  | no block at 300 $\mu$ M | 65 mm Hg at 1.5 $\mu$ moles/kg i.v., 60 min duration  |
| 5 Compound 2   | 10 - 30 $\mu$ M  | no block at 100 $\mu$ M | 40 mm Hg at 1.5 $\mu$ moles/kg i.v., 120 min duration |
| Compound 3     | 10 - 30 $\mu$ M  | not tested              | 20 mm Hg at 1 mg/kg s.c., > 60 min duration           |
| Compound 4     | 10 - 100 $\mu$ M   | no block at 100 $\mu$ M | 40 mm Hg at 1.5 $\mu$ moles/kg i.v., 120 min duration |
| Compound 9     | 10 - 100 $\mu$ M   | no block at 300 $\mu$ M | 75 mm Hg at 4.5 $\mu$ moles/kg i.v., 90 min duration  |
| Compound 11    | not tested   | not tested              | 20 mm Hg at 1 mg/kg i.v., 30 min duration             |
| 10 Compound 12 | not tested   | not tested              | no effect at doses up to 37.3 $\mu$ moles/kg i.v.     |
| Compound 14    | not tested   | not tested              | no effect at doses up to 15 $\mu$ moles/kg i.v.       |
| Compound 19    | 100 - 300 $\mu$ M  | block at 100 $\mu$ M    | not tested  |

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|             |                  |                      |   |
|-------------|------------------|----------------------|---|
| Compound 20 | 30 - 300 $\mu$ M | block at 100 $\mu$ M | no effect at doses up to 15 $\mu$ moles/kg i.v. |
| Compound 22 | not tested       | not tested           | no effect at doses up to 15 $\mu$ moles/kg i.v. |

<sup>a</sup>:Concentration which suppresses NMDA receptor-mediated synaptic transmission (see Example 5).

5 <sup>b</sup>:Concentration that does not block the induction of LTP (see Example 19).

<sup>c</sup>:Drop in systemic blood pressure produced by administration of compound in rats (see Example 22).

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### Formulation and Administration

As demonstrated herein, useful compounds of this invention and their pharmaceutically acceptable salts may be used to treat neurological disorders or diseases. While these compounds will typically be used in therapy for human patients, they may also be used to treat similar or identical diseases in other vertebrates such as other primates, farm animals such as swine, cattle and poultry, and sports animals and pets such as horses, dogs and cats.

In therapeutic and/or diagnostic applications, the compounds of the invention can be formulated for a variety of modes of administration, including systemic and topical or localized administration. Techniques and formulations generally may be found in *Remington's Pharmaceutical Sciences*, Mack Publishing Co., Easton PA (18th ed. 1990).

Pharmaceutically acceptable salts are generally well known to those of ordinary skill in the art, and may include, by way of example but not limitation, acetate, benzenesulfonate, besylate, benzoate, bicarbonate, bitartrate, calcium edetate, camsylate, carbonate, citrate, edetate, edisylate, estolate, esylate, fumarate, gluceptate, gluconate, glutamate, glycolylarsanilate, hexylresorcinate, hydrabamine, hydrobromide, hydrochloride, hydroxynaphthoate, iodide, isethionate, lactate, lactobionate, malate, maleate, mandelate, mesylate, mucate, napsylate, nitrate, pamoate (embonate), pantothenate, phosphate/disphosphate, polygalacturonate,

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salicylate, stearate, subacetate, succinate, sulfate, tannate, tartrate, or teoclate. Other pharmaceutically acceptable salts may be found in, for example, *Remington's Pharmaceutical Sciences*, Mack Publishing Co., Easton, PA (18th ed. 1990).

Preferred pharmaceutically acceptable salts include, for example, acetate, benzoate, bromide, carbonate, citrate, gluconate, hydrobromide, hydrochloride, maleate, mesylate, napsylate pamoate (embonate), phosphate, salicylate, succinate, sulfate, or tartrate.

The useful compounds of this invention may also be in the form of pharmaceutically acceptable complexes. Pharmaceutically acceptable complexes are known to those of ordinary skill in the art and include, by way of example but not limitation, 8-chlorotheophyllinate (teoclate).

The exact formulation, route of administration and dosage can be chosen by the individual physician in view of the patient's condition. (See e.g. Fingl et al., in The Pharmacological Basis of Therapeutics, 1975, Ch. 1 p. 1).

It should be noted that the attending physician would know how and when to terminate, interrupt, or adjust administration due to toxicity or organ dysfunction. Conversely, the attending physician would also know to adjust treatment to higher levels if the clinical responses were not adequate (precluding toxicity). The magnitude of an administered dose in the management of the disorder of interest will vary with



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the severity of the condition to be treated and to the route of administration. The severity of the condition may, for example, be evaluated in part, by standard prognostic evaluation methods. Further, the dose and perhaps dose frequency, will also vary according to the  
5 age, body weight, and response of the individual patient. A program comparable to that discussed above may be used in veterinary medicine.

Depending on the specific conditions being  
10 treated, such agents may be formulated into liquid or solid dosage forms and administered systemically or locally. The agents may be delivered, for example, in a timed or sustained-release form as is known to those skilled in the art. Techniques for formulation and  
15 administration may be found in *Remington's Pharmaceutical Sciences*, Mack Publishing Co., Easton, PA (18th ed. 1990). Suitable routes may include oral, buccal, sublingual, rectal, transdermal, vaginal, transmucosal, nasal or intestinal administration;  
20 parenteral delivery, including intramuscular, subcutaneous, intramedullary injections, as well as intrathecal, direct intraventricular, intravenous, intraperitoneal, intranasal, or intraocular injections, just to name a few.

25 For injection, the agents of the invention may be formulated in aqueous solutions, preferably in physiologically compatible buffers such as Hank's solution, Ringer's solution, or physiological saline buffer. For such transmucosal administration,  
30 penetrants appropriate to the barrier to be permeated

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are used in the formulation. Such penetrants are generally known in the art.

Use of pharmaceutically acceptable carriers to formulate the compounds herein disclosed for the practice of the invention into dosages suitable for systemic administration is within the scope of the invention. With proper choice of carrier and suitable manufacturing practice, the compositions of the present invention, in particular, those formulated as solutions, may be administered parenterally, such as by intravenous injection. The compounds can be formulated readily using pharmaceutically acceptable carriers well known in the art into dosages suitable for oral administration. Such carriers enable the compounds of the invention to be formulated as tablets, pills, capsules, liquids, gels, syrups, slurries, suspensions and the like, for oral ingestion by a patient to be treated.

Agents intended to be administered intracellularly may be administered using techniques well known to those of ordinary skill in the art. For example, such agents may be encapsulated into liposomes, then administered as described above. Liposomes are spherical lipid bilayers with aqueous interiors. All molecules present in an aqueous solution at the time of liposome formation are incorporated into the aqueous interior. The liposomal contents are both protected from the external microenvironment and, because liposomes fuse with cell membranes, are efficiently delivered into the cell cytoplasm. Additionally, due to their hydrophobicity, small organic molecules may be

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directly administered intracellularly.

Pharmaceutical compositions suitable for use in the present invention include compositions wherein the active ingredients are contained in an effective  
5 amount to achieve its intended purpose. Determination of the effective amounts is well within the capability of those skilled in the art, especially in light of the detailed disclosure provided herein.

In addition to the active ingredients, these  
10 pharmaceutical compositions may contain suitable pharmaceutically acceptable carriers comprising excipients and auxiliaries which facilitate processing of the active compounds into preparations which can be used pharmaceutically. The preparations formulated for  
15 oral administration may be in the form of tablets, dragees, capsules, or solutions.

The pharmaceutical compositions of the present invention may be manufactured in a manner that is itself known, e.g., by means of conventional mixing,  
20 dissolving, granulating, dragee-making, levigating, emulsifying, encapsulating, entrapping or lyophilizing processes.

Pharmaceutical formulations for parenteral administration include aqueous solutions of the active  
25 compounds in water-soluble form. Additionally, suspensions of the active compounds may be prepared as appropriate oily injection suspension. Suitable lipophilic solvents or vehicles include fatty oils such as sesame oil, or synthetic fatty acid ester, such as  
30 ethyl oleate or triglycerides, or liposomes. Aqueous

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injection suspensions may contain substances which increase the viscosity of the suspension, such as sodium carboxymethyl cellulose, sorbitol, or dextran.

Optionally, the suspension may also contain suitable stabilizers or agents which increase the solubility of the compounds to allow for the preparation of highly concentrated solutions.

Pharmaceutical preparations for oral use can be obtained by combining the active compounds with solid excipients, optionally grinding a resulting mixture, and processing the mixture of granules, after adding suitable auxiliaries, if desired, to obtain tablets or dragee cores. Suitable excipients are, in particular, fillers such as sugars, including lactose, sucrose, mannitol, or sorbitol; cellulose preparations, for example, maize starch, wheat starch, rice starch, potato starch, gelatin, gum tragacanth, methyl cellulose, hydroxypropylmethyl-cellulose, sodium carboxymethylcellulose (CMC), and/or polyvinylpyrrolidone (PVP: povidone). If desired, disintegrating agents may be added, such as the cross-linked polyvinylpyrrolidone, agar, or alginic acid or a salt thereof such as sodium alginate.

Dragee cores are provided with suitable coatings. For this purpose, concentrated sugar solutions may be used, which may optionally contain gum arabic, talc, polyvinylpyrrolidone, carbopol gel, polyethylene glycol (PEG), and/or titanium dioxide, lacquer solutions, and suitable organic solvents or solvent mixtures. Dye-stuffs or pigments may be added

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to the tablets or dragee coatings for identification or to characterize different combinations of active compound doses.

Pharmaceutical preparations which can be used orally include push-fit capsules made of gelatin, as well as soft, sealed capsules made of gelatin, and a plasticizer, such as glycerol or sorbitol. The push-fit capsules can contain the active ingredients in admixture with filler such as lactose, binders such as starches, and/or lubricants such as talc or magnesium stearate and, optionally, stabilizers. In soft capsules, the active compounds may be dissolved or suspended in suitable liquids, such as fatty oils, liquid paraffin, or liquid polyethylene glycols (PEGs). In addition, stabilizers may be added.

Other embodiments are within the following claims.

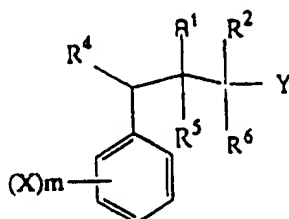
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## Claims

1. A compound of formula I:



FORMULA I

wherein:

5           R<sup>1</sup> and R<sup>5</sup> are independently selected from the group consisting of phenyl, benzyl, and phenoxy (each of which is optionally substituted with alkyl, hydroxyalkyl, -OH, -O-alkyl, -O-acyl, -F, -Cl, -Br, -I, -CF<sub>3</sub>, or -OCF<sub>3</sub>), -H, alkyl, hydroxyalkyl, -OH, -O-alkyl, and O-acyl;

10           R<sup>2</sup> and R<sup>6</sup> are independently selected from the group consisting of -H, alkyl, and hydroxyalkyl; or R<sup>2</sup> and R<sup>6</sup> together are imino; or R<sup>1</sup> and R<sup>2</sup> together are -(CH<sub>2</sub>)<sub>n</sub>- or -(CH<sub>2</sub>)<sub>n</sub>-N(R<sup>3</sup>)-(CH<sub>2</sub>)<sub>n</sub>-;

          R<sup>3</sup> is independently selected from the group  
15           consisting of -H, alkyl, 2-hydroxyethyl and alkylphenyl;  
          n is an integer from 0 to 6, but at least one n must be greater than 0;

          R<sup>4</sup> is selected from the group consisting of  
          thiofuran, pyridyl, phenyl, benzyl, phenoxy, and  
20           phenylthio (each of which is optionally substituted  
          with alkyl, -F, -Cl, -Br, -I, -CF<sub>3</sub>, -OH, -OCF<sub>3</sub>, -O-alkyl,  
          or -O-acyl), -H, alkyl and cycloalkyl;

          X is independently selected from the group  
          consisting of phenyl, benzyl, and phenoxy (each of which  
25           is optionally substituted with -F, -Cl, -Br, -I, -CF<sub>3</sub>,  
          alkyl, -OH, -OCF<sub>3</sub>, -O-alkyl, or -O-acyl) -F, -Cl, -Br,

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-I, CF<sub>3</sub>, alkyl, -OH, -OCF<sub>3</sub>, -O-alkyl, and O-acyl;

m is independently an integer from 0 to 5;

Y is -NR<sup>1</sup>R<sup>2</sup>, except when R<sup>1</sup> and R<sup>2</sup> together are  
-(CH<sub>2</sub>)<sub>n</sub>-N(R<sup>3</sup>)-(CH<sub>2</sub>)<sub>n</sub>-, then Y is -H;

5 and pharmaceutically acceptable salts and complexes thereof, wherein the compound is active at an NMDA receptor.

2. The compound of claim 1, wherein:

Y is selected from the group consisting of -NH<sub>2</sub> and  
10 -NH-methyl;

R<sup>4</sup> is thiofuran, pyridyl, phenyl, benzyl, phenoxy, or phenylthio, each of which is optionally substituted with -F, -Cl, -Br, -I, -CF<sub>3</sub>, alkyl, -OH, -OCF<sub>3</sub>, -O-alkyl, or -O-acyl;

15 X is independently selected from the group consisting of meta-fluoro, meta-chloro, ortho-O-lower alkyl, ortho-methyl, ortho-fluoro, ortho-chloro, meta-O-lower alkyl, meta-methyl, ortho-OH, and meta-OH; and either

20 R<sup>1</sup>, R<sup>2</sup>, R<sup>5</sup>, and R<sup>6</sup> are -H;  
or R<sup>2</sup> is methyl, and R<sup>1</sup>, R<sup>5</sup>, and R<sup>6</sup> are -H;  
or R<sup>1</sup> is methyl, and R<sup>2</sup>, R<sup>5</sup>, and R<sup>6</sup> are -H.

3. The compound of claim 1, wherein:

R<sup>1</sup> and R<sup>5</sup> are independently selected from the group  
25 consisting of -H, lower alkyl, hydroxyalkyl, -OH, -O-alkyl, and -O-acyl;

R<sup>2</sup> and R<sup>6</sup> are independently selected from the group consisting of -H, lower alkyl, and hydroxyalkyl;

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or R<sup>1</sup> and R<sup>2</sup> together are -(CH<sub>2</sub>)<sub>n</sub>- or  
-(CH<sub>2</sub>)<sub>n</sub>-N(R<sup>3</sup>)-, and Y is H;

R<sup>3</sup> is independently selected from the group  
consisting of -H and lower alkyl;

5 R<sup>4</sup> is selected from the group consisting of  
thiofuran, pyridyl, phenyl, benzyl, phenoxy, and  
phenylthio (each of which is optionally substituted with  
lower alkyl, -F, -Cl, -Br, -I, -CF<sub>3</sub>, -OH, -OCF<sub>3</sub>,  
-O-alkyl, or -O-acyl), -H, lower alkyl, and cycloalkyl;

10 X is independently selected from the group  
consisting of -F, -Cl, -Br, -I, -CF<sub>3</sub>, lower alkyl, -OH,  
and -OCF<sub>3</sub>;

m is independently an integer from 0 to 5;

15 Y is -NHR<sup>3</sup>, or hydrogen when R<sup>1</sup> and R<sup>2</sup> together are  
-(CH<sub>2</sub>)<sub>n</sub>-N(R<sup>3</sup>)-, and pharmaceutically acceptable salts and  
complexes thereof, with the provisos that

(a) when R<sup>1</sup> and R<sup>2</sup> together are -(CH<sub>2</sub>)<sub>n</sub>-N(R<sup>3</sup>)-, then  
R<sup>5</sup>, R<sup>6</sup>, and Y are hydrogens; and

20 (b) when R<sup>1</sup> and R<sup>2</sup> together are not (CH<sub>2</sub>)<sub>n</sub>-N(R<sup>3</sup>)-,  
then Y is -NHR<sup>3</sup>.

4. The compound of claim 1, wherein:

X is independently selected from the group  
consisting of -F, -Cl, -Br, -I, -CF<sub>3</sub>, alkyl, -OH, -OCF<sub>3</sub>,  
-O-alkyl, and -O-acyl;

25 R<sup>1</sup> is selected from the group consisting of -H,  
alkyl, hydroxyalkyl, -OH, -O-alkyl, and -O-acyl;

R<sup>2</sup> and R<sup>6</sup> are selected from the group consisting of  
-H, alkyl, and hydroxyalkyl, or R<sup>2</sup> and R<sup>6</sup> together are  
imino;



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R<sup>5</sup> is independently selected from the group consisting of -H, alkyl, hydroxyalkyl, -OH, -O-alkyl, and -O-acyl; and

Y is NR<sup>3</sup>R<sup>3</sup>.

5           5.    The compound of claim 1, wherein:

X is independently selected from the group consisting of -F, -Cl, -Br, -I, -CF<sub>3</sub>, alkyl, -OH, -OCF<sub>3</sub>, -O-alkyl, and -O-acyl;

10           R<sup>1</sup> is selected from the group consisting of -H, alkyl, hydroxyalkyl, -OH, -O-alkyl, and -O-acyl;

R<sup>2</sup> and R<sup>6</sup> are independently selected from the group consisting of -H, alkyl, and hydroxyalkyl, or R<sup>2</sup> and R<sup>6</sup> together are imino;

15           R<sup>5</sup> is selected from the group consisting of -H, alkyl, hydroxyalkyl, -OH, -O-alkyl, and -O-acyl;

Y is NR<sup>3</sup>R<sup>3</sup>; and

R<sup>4</sup> is phenyl, optionally substituted with alkyl, -F, -Cl, -Br, -I, -CF<sub>3</sub>, -OH, -OCF<sub>3</sub>, -O-alkyl, or -O-acyl.

6.    The compound of claim 1, wherein:

20           R<sup>3</sup> is independently selected from the group consisting of -H, and alkyl;

R<sup>4</sup> is phenyl, optionally substituted with alkyl, -F, -Cl, -Br, -I, -CF<sub>3</sub>, -OH, -OCF<sub>3</sub>, -O-alkyl, or -O-acyl; and

R<sup>1</sup> and R<sup>2</sup> together are -(CH<sub>2</sub>)<sub>n</sub>- or -(CH<sub>2</sub>)<sub>n</sub>-N(R<sup>3</sup>)-.

25           7.    The compound of claim 1, wherein:

X is independently selected from the group consisting of -F, -Cl, -Br, -I, CF<sub>3</sub>, alkyl, -OH, -OCF<sub>3</sub>,

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-O-alkyl, and -O-acyl; and

$R^1$  and  $R^2$  together are  $-(CH_2)_n-$  or  $-(CH_2)_n-N(R^3)-$ .

8. The compound of claim 1, wherein:

X is independently selected from the group  
5 consisting of meta-fluoro, meta-chloro, ortho-O-lower  
alkyl, ortho-methyl, ortho-fluoro, ortho-chloro,  
meta-O-lower alkyl, meta-methyl, ortho-OH, and meta-OH;

$NR^3$  is selected from the group consisting of NH,  
N-methyl, and N-ethyl;

10  $NR^3R^3$  is selected from the group consisting of  $NH_2$ ,  
NH-methyl, and NH-ethyl;

$R^1$  is selected from the group consisting of -H and  
methyl;

$R^2$  is selected from the group consisting of -H and  
15 methyl; and

$R^4$  is selected from the group consisting of phenyl,  
benzyl, and phenoxy, each of which is optionally  
substituted with alkyl, -F, -Cl, -Br, -F, -CF<sub>3</sub>, -OH,  
-OCF<sub>3</sub>, -O-alkyl, or -O-acyl.

20 9. The compound of claim 1, wherein:

X is meta-fluoro;

each  $R^1$  and  $R^2$  is -H;

$NR^3$  is selected from the group consisting of NH and  
N-methyl;

25  $NR^3R^3$  is selected from the group consisting of  $NH_2$   
and NH-methyl; and

$R^4$  is selected from the group consisting of phenyl,  
benzyl, and phenoxy, each of which is optionally

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substituted with alkyl, -F, -Cl, -Br, -I,  
-CF<sub>3</sub>, -OH, -OCF<sub>3</sub>, -O-alkyl, or -O-acyl.

10. The compound of claim 4, wherein:

5 X is independently selected from the group  
consisting of meta-fluoro, meta-chloro, ortho-O-lower  
alkyl, ortho-methyl, ortho-fluoro, ortho-chloro,  
meta-O-lower alkyl, meta-methyl, ortho-OH, and meta-OH;

NR<sup>3</sup> is selected from the group consisting of NH,  
N-methyl, and N-ethyl;  
10 NR<sup>3</sup>R<sup>3</sup> is selected from the group consisting of NH<sub>2</sub>,  
NH-methyl, and NH-ethyl;

R<sup>1</sup> is selected from the group consisting of -H and  
methyl;

R<sup>2</sup> is selected from the group consisting of -H and  
15 methyl; and

R<sup>4</sup> is selected from the group consisting of phenyl,  
benzyl, and phenoxy, each of which is optionally  
substituted with alkyl, -F, -Cl, -Br, -I, -CF<sub>3</sub>, -OH,  
-OCF<sub>3</sub>, -O-alkyl, or -O-acyl.

20 11. The compound of claim 4, wherein:

X is meta-fluoro;

NR<sup>3</sup> is selected from the group consisting of NH and  
N-methyl;

NR<sup>3</sup>R<sup>3</sup> is selected from the group consisting of NH<sub>2</sub>  
25 and NH-methyl;

R<sup>1</sup> is -H;

R<sup>2</sup> is -H; and

R<sup>4</sup> is selected from the group consisting of phenyl,

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benzyl, and phenoxy, each of which is optionally substituted with alkyl, -F, -Cl, -Br, -I, -CF<sub>3</sub>, -OH, -OCF<sub>3</sub>, -O-alkyl, or O-acyl.

12. The compound of claim 5, wherein:

5 X is independently selected from the group consisting of meta-fluoro, meta-chloro, ortho-O-lower alkyl, ortho-methyl, ortho-fluoro, ortho-chloro, meta-O-lower alkyl, meta-methyl, ortho-OH, and meta-OH;

NR<sup>3</sup> is selected from the group consisting of NH,  
10 N-methyl, and N-ethyl;

NR<sup>3</sup>R<sup>3</sup> is selected from the group consisting of NH<sub>2</sub>, NH-methyl, and NH-ethyl;

R<sup>1</sup> is selected from the group consisting of -H and methyl;

15 R<sup>2</sup> is selected from the group consisting of -H and methyl;

and R<sup>4</sup> is selected from the group consisting of phenyl, benzyl, and phenoxy, each of which is optionally substituted with alkyl, -F, -Cl, -Br, -I, -CF<sub>3</sub>, -OH,  
20 -OCF<sub>3</sub>, -O-alkyl, or O-acyl.

13. The compound of claim 5, wherein:

X is meta-fluoro;

NR<sup>3</sup> is selected from the group consisting of NH and N-methyl;

25 NR<sup>3</sup>R<sup>3</sup> is selected from the group consisting of NH<sub>2</sub> and NH-methyl;

R<sup>1</sup> is -H;

R<sup>2</sup> is -H; and

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R<sup>4</sup> is selected from the group consisting of phenyl, benzyl, and phenoxy, each of which is optionally substituted with alkyl, -F, -Cl, -Br, -I, -CF<sub>3</sub>, -OH, -OCF<sub>3</sub>, -O-alkyl, or O-acyl.

5           14. The compound of claim 6, wherein:

X is independently selected from the group consisting of meta-fluoro, meta-chloro, ortho-O-lower alkyl, ortho-methyl, ortho-fluoro, ortho-chloro, meta-O-lower alkyl, meta-methyl, ortho-OH, and meta-OH;

10           NR<sup>3</sup> is selected from the group consisting of NH, N-methyl, and N-ethyl;

NR<sup>3</sup>R<sup>3</sup> is selected from the group consisting of NH<sub>2</sub>, NH-methyl, and NH-ethyl;

15           R<sup>1</sup> is selected from the group consisting of -H and methyl;

R<sup>2</sup> is selected from the group consisting of -H and methyl; and

20           R<sup>4</sup> is selected from the group consisting of phenyl, benzyl, and phenoxy, each of which is optionally substituted with alkyl, -F, -Cl, -Br, -I, -CF<sub>3</sub>, -OH, -OCF<sub>3</sub>, -O-alkyl, or O-acyl.

15. The compound of claim 6, wherein:

X is meta-fluoro;

25           NR<sup>3</sup> is selected from the group consisting of NH and N-methyl;

NR<sup>3</sup>R<sup>3</sup> is selected from the group consisting of NH<sub>2</sub> and NH-methyl;

R<sup>1</sup> is -H;

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R<sup>2</sup> is -H; and

R<sup>4</sup> is selected from the group consisting of phenyl, benzyl, and phenoxy, each of which is optionally substituted with alkyl, -F, -Cl, -Br, -I, -CF<sub>3</sub>, -OH, -OCF<sub>3</sub>, -O-alkyl, or O-acyl.

16. The compound of claim 7, wherein:

X is independently selected from the group consisting of meta-fluoro, meta-chloro, ortho-O-lower alkyl, ortho-methyl, ortho-fluoro, ortho-chloro, meta-O-lower alkyl, meta-methyl, ortho-OH, and meta-OH;

NR<sup>3</sup> is selected from the group consisting of NH, N-methyl, and N-ethyl;

NR<sup>3</sup>R<sup>3</sup> is selected from the group consisting of NH<sub>2</sub>, NH-methyl, and NH-ethyl;

R<sup>1</sup> is selected from the group consisting of -H and methyl;

R<sup>2</sup> is selected from the group consisting of -H and methyl; and

R<sup>4</sup> is selected from the group consisting of phenyl, benzyl, and phenoxy, each of which is optionally substituted with alkyl, -F, -Cl, -Br, -I, -CF<sub>3</sub>, -OH, -OCF<sub>3</sub>, -O-alkyl, or O-acyl.

17. The compound of claim 7, wherein:

X is meta-fluoro;

NR<sup>3</sup> is selected from the group consisting of NH and N-methyl;

NR<sup>3</sup>R<sup>3</sup> is selected from the group consisting of NH<sub>2</sub> and NH-methyl;

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R<sup>1</sup> is -H;

R<sup>2</sup> is -H; and

R<sup>4</sup> is selected from the group consisting of phenyl, benzyl, and phenoxy, each of which is optionally substituted with alkyl, -F, -Cl, -Br, -I, -CF<sub>3</sub>, -OH, -OCF<sub>3</sub>, -O-alkyl, or O-acyl.

18. A compound selected from the group consisting of Compound 21, 22, 23, 24, 25, 27, 28, 29, 33, 34, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 69, 76, 78, 79, 82, 83, 84, 88, 89, 90, 92, 93, 94, 95, 96, 98, 101, 102, 103, 105, 107, 108, 109, 111, 115, 116, 118, 119, 120, 121, 122, 124, 125, 126, 127, 129, 130, 131, 134, 135, 136, 137, 138, 139, 141, 142, 143, 144, 145, 148, 149, and 150, and pharmaceutically acceptable salts and complexes thereof, wherein the compound is active at an NMDA receptor.

19. The compound of claim 18, selected from the group consisting of Compound 21, 22, 23, 24, 25, 27, 28, 29, 33, 34, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 69, 76, 82, 83, 88, 89, 90, 92, 93, 94, 95, 96, 101, 102, 103, 105, 108, 109, 111, 115, 118, 119, 120, 121, 122, 125, 126, 127, 129, 130, 131, 135, 136, 137, 138, 139, 142, 144, 145, 148, 149, and 150.

20. The compound of claim 19, selected from the group consisting of Compound 21, 22, 23, 24, 25, 27, 28,

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33, 38, 39, 43, 44, 46, 47, 49, 50, 52, 53, 54, 55, 56,  
57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 69, 82, 83, 89,  
90, 93, 94, 95, 96, 103, 111, 118, 119, 120, 122, 126,  
135, 136, 137, 138, 142, 144, 145, 148, 149 and 150.

5           21. The compound of claim 20, selected from the  
group consisting of Compound 24, 25, 33, 50, 60, 66, 69,  
103, 111, 118, 119, 120, 122, 136, 137, 138, 142, 144,  
145, 148, 149 and 150.

          22. The compound of claim 21, wherein said  
10 compound is Compound 20.

          23. The compound of claim 21, wherein said  
compound is Compound 33.

          24. The compound of claim 21, wherein said  
compound is Compound 50.

15           25. The compound of claim 21, wherein said  
compound is Compound 60.

          26. The compound of claim 21, wherein said  
compound is Compound 119.

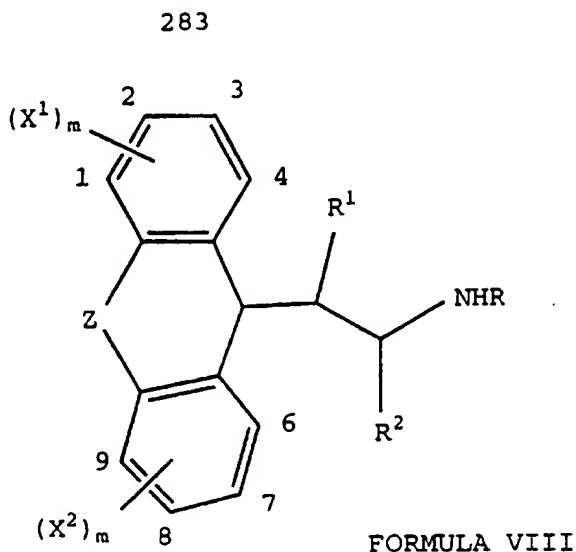
          27. The compound of claim 21, wherein said  
20 compound is Compound 144.

          28. A compound of Formula VIII:



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wherein:

Z is selected from the group consisting of -CH<sub>2</sub>CH<sub>2</sub>-, -CH<sub>2</sub>CH(CH<sub>3</sub>)-, -CH=CH-, -O-CH<sub>2</sub>-, -S-CH<sub>2</sub>-, -O-, and -S-;

X<sup>1</sup> and X<sup>2</sup> are independently selected from the group consisting of -F, -Cl, -CH<sub>3</sub>, -OH, and lower O-alkyl in the 1-, 3-, 7-, or 9-substituent positions;

m is independently an integer from 0 to 2;

-NHR is selected from the group consisting of -NH<sub>2</sub>, -NHCH<sub>3</sub>, and -NHC<sub>2</sub>H<sub>5</sub>;

R<sup>1</sup> is selected from the group consisting of -H, alkyl, hydroxyalkyl, -OH, -O-alkyl, and -O-acyl, and

R<sup>2</sup> is selected from the group consisting of -H, alkyl, hydroxyalkyl, and pharmaceutically acceptable salts and complexes thereof, wherein the compound is active at an NMDA receptor.

29. The compound of claim 28, wherein:

Z is -CH<sub>2</sub>CH<sub>2</sub>-;

X<sup>1</sup> or X<sup>2</sup> is -F, or both X<sup>1</sup> and X<sup>2</sup> are -F;

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either R<sup>1</sup> or R<sup>2</sup> is methyl or both R<sup>1</sup> and R<sup>2</sup> are -H;  
and

-NHR is selected from the group consisting of -  
NH<sub>2</sub> or -NHCH<sub>3</sub>.

5        30. A compound selected from the group consisting  
of Compound 151, 152, 153, 154, 155, 157, 158, 159, 163,  
164, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175,  
176, 181, 185, 186, 188, 189, 190, 191, 192, 193, 194,  
195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205,  
10      206, 207, 208, 209, 210, 211, 212, 213, 214, 215 and  
pharmaceutically acceptable salts and complexes thereof.

31. The compound of claim 30, wherein said  
compound is selected from the group consisting of  
Compound 157, 158, 159, 163, 164, 166, 167, 168, 169,  
15      170, 171, 181, 185, 186, and pharmaceutically acceptable  
salts and complexes thereof.

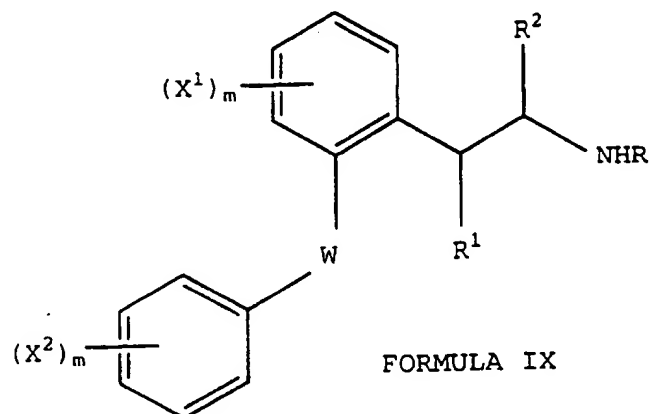
32. The compound of claim 30, wherein said  
compound is selected from the group consisting of  
Compound 157, 158, 159, 163, 164, 167, 168, 169, 170,  
20      171, 181, 186, and pharmaceutically acceptable salts and  
complexes thereof.

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33. A compound of formula IX:



wherein:

W is selected from the group consisting of -CH<sub>2</sub>-,  
5 -O-, and -S-;

X<sup>1</sup> and X<sup>2</sup> are independently selected from the group  
consisting of -F, -Cl, -CH<sub>3</sub>, -OH, and lower O-alkyl;

m is independently an integer from 0 to 2;

-NHR is selected from the group consisting of -NH<sub>2</sub>,  
10 -NHCH<sub>3</sub>, and -NHC<sub>2</sub>H<sub>5</sub>;

R<sup>1</sup> is selected from the group consisting of -H,  
alkyl, hydroxyalkyl, -OH, -O-alkyl, and -O-acyl; and

R<sup>2</sup> is selected from the group consisting of -H,  
alkyl, hydroxyalkyl, and pharmaceutically acceptable  
15 salts and complexes thereof, wherein the compound is  
active at an NMDA receptor.

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34. The compound of claim 33, selected from the group consisting of compound 128, 129, 130, 131, 132, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, and 215.

5           35. A method for treating a patient having a neurological disease or disorder, comprising administering a compound as in any of claims 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 28, 29, or 33.

10           36. A method for treating a patient having a neurological disease or disorder, comprising administering a compound selected from the group consisting of Compound 19, 20, 21, 22, 23, 24, 25, 27, 28, 29, 30, 31, 32, 33, 34, 37, 38, 39, 40, 41, 42, 43, 15 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 75, 76, 77, 78, 79, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 100, 101, 102, 103, 105, 106, 107, 108, 109, 111, 114, 115, 116, 20 117 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 141, 142, 143, 144, 145, 146, 147, 148, 149, and 150, and pharmaceutically acceptable salts and complexes thereof, wherein the compound is active at an NMDA 25 receptor.

37. The method of claim 36, wherein said compound is selected from the group consisting of Compound 19,

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20, 21, 22, 23, 24, 25, 27, 28, 29, 30, 31, 32, 33, 34,  
37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50,  
51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64,  
65, 66, 69, 70, 75, 76, 81, 82, 83, 85, 86, 87, 88, 89,  
5 90, 91, 92, 93, 94, 95, 96, 97, 100, 101, 102, 103, 105,  
106, 108, 109, 111, 115, 118, 119, 120, 121, 122, 125,  
126, 127, 128, 129, 130, 131, 132, 133, 135, 136, 137,  
138, 139, 142, 144, 145, 146, 147, 148, 149, and 150,  
and pharmaceutically acceptable salts and complexes  
10 thereof.

38. The method of claim 36, wherein said compound  
is selected from the group consisting of Compound 19,  
20, 21, 22, 23, 24, 25, 27, 28, 30, 31, 32, 33, 38, 39,  
43, 44, 46, 47, 49, 50, 52, 53, 54, 55, 56, 57, 58, 59,  
15 60, 61, 62, 63, 64, 65, 66, 69, 82, 83, 89, 90, 91, 93,  
94, 95, 96, 97, 103, 111, 118, 119, 120, 122, 126, 135,  
136, 137, 138, 142, 144, 145, 147, 148, 149, and 150,  
and pharmaceutically acceptable salts and complexes  
thereof.

20 39. The method of claim 36, wherein said compound  
is selected from the group consisting of Compound 20,  
24, 25, 33, 50, 60, 66, 69, 103, 111, 118, 119, 120,  
122, 136, 137, 138, 142, 144, 145, 148, 149, and 150,  
and pharmaceutically acceptable salts and complexes  
25 thereof.

40. The method of claim 36, wherein said compound

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is Compound 20, and pharmaceutically acceptable salts and complexes thereof.

41. The method of claim 36, wherein said compound is Compound 33, and pharmaceutically acceptable salts  
5 and complexes thereof.

42. The method of claim 36, wherein said compound is Compound 50, and pharmaceutically acceptable salts and complexes thereof.

43. The method of claim 36, wherein said compound  
10 is Compound 60, and pharmaceutically acceptable salts and complexes thereof.

44. The method of claim 36, wherein said compound is Compound 119, and pharmaceutically acceptable salts and complexes thereof.

15 45. The method of claim 36, wherein said compound is Compound 144, and pharmaceutically acceptable salts and complexes thereof.

46. A method for treating a patient having a neurological disease or disorder, comprising  
20 administering a compound selected from the group consisting of Compound 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189,

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190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200,  
201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211,  
212, 213, 214, 215 and pharmaceutically acceptable salts  
and complexes thereof.

5           47. The method of claim 46, wherein said compound  
is selected from the group consisting of Compound 156,  
157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167,  
168, 169, 170, 171, 181, 182, 183, 184, 185, 186, 187,  
and pharmaceutically acceptable salts and complexes  
10 thereof.

          48. The method of claim 46, wherein said compound  
is selected from the group consisting of Compound 156,  
157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167,  
168, 169, 170, 171, 181, 183, 184, 185, 186, 187, and  
15 pharmaceutically acceptable salts and complexes thereof.

          49. The method of claim 46, wherein said compound  
is selected from the group consisting of Compound 156,  
157, 158, 159, 161, 163, 164, 165, 166, 167, 168, 169,  
170, 171, 181, 185, 186, and pharmaceutically acceptable  
20 salts and complexes thereof.

          50. The method of claim 46, wherein said compound  
is selected from the group consisting of Compound 128,  
129, 130, 131, 132, 200, 201, 202, 203, 204, 205, 206,  
207, 208, 209, 210, 211, 212, 213, 214, and 215 and  
25 pharmaceutically acceptable salts and complexes thereof.

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51. A pharmaceutical composition, comprising a compound as in any of claims 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 28, 29, or 33, and a pharmaceutically acceptable carrier.

5           52. A pharmaceutical composition, comprising a compound selected from the group consisting of Compound  
20, 21, 22, 23, 24, 25, 27, 28, 29, 30, 31, 32, 33, 34,  
37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50,  
51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64,  
10   65, 66, 67, 68, 69, 70, 71, 72, 73, 75, 76, 77, 78, 79,  
81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94,  
95, 96, 97, 98, 100, 101, 102, 103, 105, 106, 107, 108,  
109, 111, 114, 115, 116, 117, 118, 119, 120, 121, 122,  
123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133,  
15   134, 135, 136, 137, 138, 139, 141, 142, 143, 144, 145,  
146, 148, 149, and 150, and pharmaceutically acceptable salts and complexes thereof, and a pharmaceutically acceptable carrier.

53. The pharmaceutical composition of claim 52,  
20   wherein said compound is selected from the group consisting of Compound 20, 21, 22, 23, 24, 25, 27, 28, 29, 30, 31, 32, 33, 34, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 69, 70, 75, 76, 81, 82, 83, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97,  
25   100, 101, 102, 103, 105, 106, 108, 109, 111, 115, 118, 119, 120, 121, 122, 125, 126, 127, 128, 129, 130, 131,



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132, 133, 135, 136, 137, 138, 139, 142, 144, 145, 146,  
148, 149, and 150.

54. The pharmaceutical composition of claim 52,  
wherein said compound is selected from the group  
5 consisting of Compound 20, 21, 22, 23, 24, 25, 27, 28,  
30, 31, 32, 33, 38, 39, 43, 44, 46, 47, 49, 50, 52, 53,  
54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 69,  
82, 83, 89, 90, 91, 93, 94, 95, 96, 97, 103, 111, 118,  
119, 120, 122, 126, 135, 136, 137, 138, 142, 144, 145,  
10 148, 149 and 150.

55. The pharmaceutical composition of claim 52,  
wherein said compound is selected from the group  
consisting of Compound 20, 24, 25, 33, 50, 60, 66, 69,  
103, 111, 118, 119, 120, 122, 136, 137, 138, 142, 144,  
15 145, 148, 149, and 150.

56. The pharmaceutical composition of claim 52,  
wherein said compound is Compound 20.

57. The pharmaceutical composition of claim 52,  
wherein said compound is Compound 33.

20 58. The pharmaceutical composition of claim 52,  
wherein said compound is Compound 50.

59. The pharmaceutical composition of claim 52,  
wherein said compound is Compound 60.

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60. The pharmaceutical composition of claim 52, wherein said compound is Compound 119.

61. The pharmaceutical composition of claim 52, wherein said compound is Compound 144.

5           62. A pharmaceutical composition, comprising a compound selected from the group consisting of 151, 152, 153, 154, 155, 157, 158, 159, 163, 164, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 181, 185, 186, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 10   199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215 and pharmaceutically acceptable salts thereof, and a pharmaceutically acceptable carrier.

          63. The pharmaceutical composition of claim 62, 15 wherein said compound is selected from the group consisting of Compound 157, 158, 159, 163, 164, 166, 167, 168, 169, 170, 171, 181, 185, 186, and pharmaceutically acceptable salts thereof, and a pharmaceutically acceptable carrier.

20           64. The pharmaceutical composition of claim 62, wherein said compound is selected from the group consisting of Compound 157, 158, 159, 163, 164, 166, 167, 168, 169, 170, 171, 181, 185, 186, and pharmaceutically acceptable salts thereof, and a 25 pharmaceutically acceptable carrier.

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65. The pharmaceutical composition of claim 62, wherein said compound is selected from the group consisting of Compound 157, 158, 159, 163, 164, 167, 168, 169, 170, 171, 181, 186, and pharmaceutically acceptable salts thereof, and a pharmaceutically acceptable carrier.

66. The pharmaceutical composition of claim 62, wherein said compound is selected from the group consisting of Compound 128, 129, 130, 131, 132, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, and 215 and pharmaceutically acceptable salts thereof, and a pharmaceutically acceptable carrier.

67. A method for making a therapeutic agent comprising the steps of screening for said agent by determining whether said agent is active on a receptor-operated calcium channel, and synthesizing said therapeutic agent in an amount sufficient to provide said agent in a therapeutically effective amount to a patient.

68. The method of claim 67 wherein said receptor-operated calcium channel is an NMDA receptor.

69. The method of claim 68 wherein said therapeutic agent comprises a compound as in any of claims 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 28, 29 or 33.

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70. The method of claim 68 wherein said therapeutic agent is selected from the group consisting of Compounds 19-215.

5 71. The method of claim 68 wherein said therapeutic agent is provided to a patient having a neurological disease or disorder.

72. The method of claim 68 further comprising the step of adding a pharmaceutically acceptable carrier to said agent.

10 73. The method of claim 67 wherein said screening comprises the step of identifying a compound which binds to said receptor-operated calcium channel at a site bound by one of the arylalkylamines Compound 1, Compound 2, and Compound 3.

## INTERNATIONAL SEARCH REPORT

Intern al Application No  
PCT/US 96/20697

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 6 C07C211/00 A61K31/135 A61K31/165 A61K31/295 A61K31/40

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 A61K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages   | Relevant to claim No. |
|------------|--|-----------------------|
| X          | WO 95 21612 A (NPS PHARMA INC ;MUELLER<br>ALAN L (US); WAGENEN BRADFORD C VAN (US);)<br>17 August 1995<br>cited in the application<br>see page 29, line 31 - page 37, line 5<br>see page 66, line 30 - page 74, line 8<br>see claims 1-7,10,12-19<br>--- | 1-73                  |
| E          | WO 96 40097 A (NPS PHARMA INC) 19 December<br>1996<br>see claims 1-93<br>---   | 1-73                  |
| A          | DE 17 93 735 A (BOEHRINGER MANNHEIM GMBH)<br>26 July 1973<br>see the whole document<br>-----   | 28                    |

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

## \* Special categories of cited documents :

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
- \*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

\*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

\*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

\*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

\*A\* document member of the same patent family

Date of the actual completion of the international search

1 August 1997

Date of mailing of the international search report

24.09.97

Name and mailing address of the ISA

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Authorized officer

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## INTERNATIONAL SEARCH REPORT

1. International application No.

PCT/US 96/20697

**Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)**

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:  
Remark: Although claim(s) 35-50  
is(are) directed to a method of treatment of the human/animal  
body, the search has been carried out and based on the alleged  
effects of the compound.
2. ☐ Claims Nos.:  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such  
an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

- 1) Claims 1-27 (completely) Claims 35-73 (partially)
- 2) Claims 28-32 (completely) Claims 35-73 (partially)
- 3) Claims 33-34 (completely) Claims 35-73 (partially)

1. ☒ As all required additional search fees were timely paid by the applicant, this International Search Report covers all  
searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment  
of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report  
covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is  
restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.☒ No protest accompanied the payment of additional search fees.

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 96/20697

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s)                   | Publication<br>date              |
|---|---------------------|--|----------------------------------|
| WO 9521612 A                              | 17-08-95            | AU 8092394 A<br>CA 2182680 A<br>EP 0743853 A | 29-08-95<br>17-08-95<br>27-11-96 |
| WO 9640097 A                              | 19-12-96            | AU 6112596 A                                 | 30-12-96                         |
| DE 1793735 A                              | 26-07-73            | NONE   |                                  |